Bloomington Environmental Quality Indicators (BEQI): Green Infrastructure section UPDATE

BACKGROUND

Green infrastructure and ecosystem services

We are all familiar with the infrastructure of the built environment. Buildings, roads, water and energy utilities—they all provide valuable services essential to life in a city. But did you know that equally essential to human well-being is the green infrastructure in our cities?

Green infrastructure, as opposed to the grey infrastructure described above, is the living infrastructure in cities. Green infrastructure aims for the *"ecology-based management of water, air or energy."*[1] Trees and other vegetation, including street trees, city parks, private yards, gardens and other greenspaces, detention ponds with vegetation, and even green roofs, all play an important role in providing ecosystem services to city residents. Proper placement and maintenance of green infrastructure can result in many benefits provided to the city and its inhabitants, such as increased human health and well-being, stormwater mitigation and increased water quality, increased property values and business revenues, decreased urban heat island effects, conservation of wildlife habitats and biodiversity, and provision of food for the urban population.[2] These benefits can be thought of collectively as *ecosystem services*.

In general, ecosystem services are the *provisioning*, *supporting*, *regulating*, and *cultural* services[3] that humans derive directly or indirectly from ecosystems and their functioning.[4] In rural areas, such as forests, farms, and water bodies, the ecosystem services that are directly provided by nature include game species, fish and seafood, pharmaceuticals, food crops, timber, fuel, and fiber; these types of services are called *provisioning* services, because nature provides humans with the goods we need to survive.[5] Less obvious are services that have not traditionally been traded in the marketplace, such as nutrient cycling, soil formation, and pollination (called *supporting* ecosystem services); modulation of climate, mitigation of floods and droughts, and air and water purification (called *regulating* services); and aesthetic beauty, recreation and personal enjoyment (*cultural* services).[6] These non-use values of ecosystems are equally important or more important than the use values of goods obtained from ecosystems. This applies in particular to cities and urban areas where the large tracks of land frequently required for provisioning ecosystem services (such as crops) are scarce.

Ecosystem services are based on intricate biogeochemical processes and ecological interactions that make them difficult or expensive to duplicate with modern technology. Likewise, monetary values for these services can be difficult to assess, although estimates indicate that the earth's ecosystems amount to as

[1] Wolf, K.L. 2010. Urban Ecosystem Services: Metro Nature and Human Well-Being. In: Laband, D.N. (ed.), Linking Science and Society, Proveedings of Emerging Issues along Urban/Rural Interfaces III, Aug 2010, Atlanta, GA. Online available at http://www.naturewithin.info/CivicEco/InterfacesIII%20Prcdngs_HHWB%20Urban%20Eco%20Services.Dec2010.pdf. Last accessed 13 Jul 2011.

[2] University of Washington. "Green Cities: Good Health." Online available at http://depts.washington.edu/hhwb. Last accessed 11 Oct 2012.

[3] [MA] Millennium Ecosystem Assessment Board. 2005. *Ecosystems and Human Well-being.* France: World Health Organization. 64pp. Online available at http://www.who.int/globalchange/ecosystems/ecosys.pdf. Last accessed 13 Jul 2011.

[4] Costanza, R. R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. V. O'Neill, J. Paruelo, R.G. Raskins, P. Sutton, & M. van den Belt. 1997. The value of the world's ecosystem services and natural capital. *Nature*, 387: 253-260.

[5] MA 2005.

[6] MA 2005.

much as $28-50 trillion of services annually.[7] For example, over 100,000 species of insects and animals supply pollination of plants, providing a service vital to the successful yield of crops (as well as wild plants). One third of fruits and vegetables consumed by humans are from plants pollinated by wild pollinators, meaning that pollinating animals and insects provide free to us a service valued for the US alone at $4-6 billion dollars annually.[8]

Ecosystem services in cities

Ecosystem services are provided in cities by the urban ecosystem.[9] The urban ecosystem includes both the natural and human components of a city, as well as the interactions between these components. Components of urban ecosystems provide ecosystem services of similar and different types as those provided by rural ecosystems. Gardens and farms in both urban and rural areas, for instance, can provide an ecosystem service in the form of food for people to eat. Trees, however, provide very different ecosystem services in rural areas and in cities: in rural forests, trees either provide timber for market or sequestered carbon, while in urban areas, the primary benefits they supply are aesthetic appeal and shade. Green infrastructure, or living infrastructure, in cities provides many ecosystem services to city residents. The following sections will discuss specific urban ecosystem services provided by specific types of green infrastructure in cities, as well as green infrastructure indicators associated with each ecosystem service for the City of Bloomington.

[7] Values stated in terms of 2011 dollars, converted from 1994 dollars as presented in Costanza et al. (1997).

[8] Ecological Society of America. "Ecosystem Services." Available online at http://www.actionbioscience.org/environment/esa.html. Last accessed 11 Oct 2012.

[9] Wolf 2010.

ECOSYSTEM SERVICE #1: STORMWATER MANAGEMENT

Development and land use patterns in cities drastically change stormwater runoff patterns in urban areas as compared to natural, undeveloped lands. The 2007 Bloomington Street Tree Report frames the concept nicely:

> *"When a raindrop hits the ground, one of two things will happen. The water can either soak into the ground providing moisture to growing plants and replenishing groundwater supplies, or if there is too much water to soak in or it hits an impermeable surface, the water will become stormwater runoff."*[10]

Figure 1 below illustrates where rainfall goes before and after urban development. In natural areas, approximately 10% of rainfall originating from a storm runs off along the surface of the ground; in urban areas, however, with 75-100% impervious (or impermeable) surfaces (such as rooftops, roads and parking lots, through which water cannot penetrate), approximately 55% of the water that falls in a storm is runoff.[11]

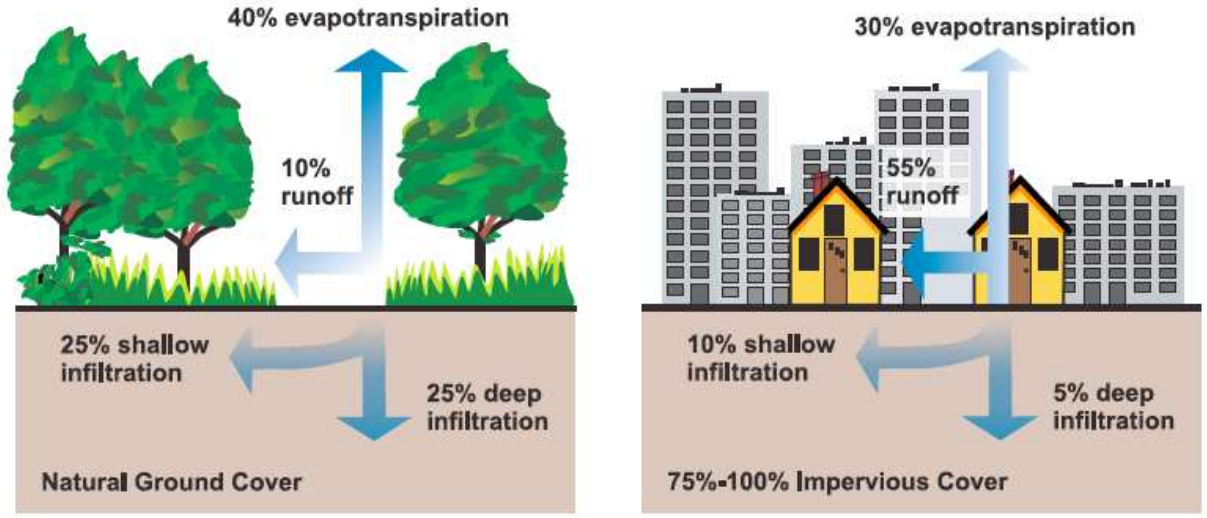

Figure 1. Changes in the destination of rainwater during and after a storm or rainfall. In natural areas, with no impervious surface cover and only natural ground cover (including much vegetation), 50% of rainfall filters into the soil, 40% is returned to the atmosphere through evaporation and transpiration by plants (see the Urban Heat Island section for more on evapotranspiration), and only 10% runs off the surface into local waterways. In urban areas, on the other hand, which can have up to 75 or 100% impervious surfaces through which water cannot penetrate, only 15% of rainfall filters directly into the ground, 30% or less is returned directly to the atmosphere through evaporation from surfaces and evapotranspiration by plants, and approximately 55% of rainfall is runoff, requiring expensive stormwater infrastructure to channel this water away from the buildings and roads in our cities. [*Source:* EPA 2003: 1]

[10] Fischer, B.C., M. Steinhoff, S. Mincey, & L. Dye. 2007. The 2007 Bloomington Street Tree Report: An Analysis of Demographics and Ecosystem Services. Bloomington Urban Forestry Report 01-07. 29pp. Online available at http://bloomington.in.gov/media/media/application/pdf/2337.pdf. Last accessed 30 June 2011. p.19.

[11] [EPA] U.S. Environmental Protection Agency. 2003. Protecting Water Quality from Urban Runoff. EPA 841-F-03-003. Washington, D.C.: United States Environmental Protection Agency, Nonpoint Source Control Branch. Online available at http://www.epa.gov/npdes/pubs/nps_urban-facts_final.pdf. Last accessed 13 Jul 2011.

As stormwater runs off urban surfaces, it gathers pollutants and contaminants along the way. Many sources contaminate stormwater: fuel and oil residues left by cars on parking lots and roads, chemicals that leach from asphalt shingles on houses and buildings, particles of air pollutants that have settled on all surfaces, chemical fertilizers and pesticides from lawns, sediment from loose soil on construction sites, and even little bits of tires that wear off during normal automobile use all end up in our stormwater.[12] Conventional grey infrastructure in cities channels this stormwater surface runoff from urban areas into underground pipes, concrete culverts (covered underground streams), and retention ponds, and eventually, back into natural water bodies. However, these mechanisms are costly to install and maintain, and can result in the accumulation of sediment and pollutants, which are then dumped into natural waterways, often with minimal filtering or treatment. (For information on stormwater management in Bloomington, see the City of Bloomington Utilities Department website and the Monroe County Highway Department's Stormwater Quality webpage.)

Low impact development (LID) uses a combination of site and building design strategies to reduce the quantity of runoff from a site, limit the impact of the development on the amount of contaminants contained in that runoff, and decrease costs of stormwater management on the site.[13][14] Low impact development methods have been shown by EPA studies to result in 15-80% cost savings due to reduced or avoided costs for site grading and preparation, stormwater piping and culverts, site paving, and landscaping.[15] LID methods include use of green, or living, infrastructure (such as trees, vegetation in stormwater ponds and on slopes, and specially designed landscaping that allows water to filter into the ground rather than drain off site) to minimize the change in stormwater runoff and infiltration resulting from development.[16] By decreasing both the total amount of water and the peak flow of water delivered to the stormwater sewer system, green infrastructure can also help decrease the number of combined sewer overflows (CSOs) occurring per year, and decrease the severity of those that do still occur.[17]

Green infrastructure helps decrease the amount of runoff discharged to stormwater sewers after a large rainstorm through three main mechanisms:

1. First, green infrastructure's pervious surfaces help absorb rainwater into the ground where it falls. When rain lands on impervious surfaces, water cannot sink into the ground. Instead, it flows downhill and pools in low places or drains into a storm sewer. Pervious surfaces, in contrast, handle rain where it falls rather than moving the problem somewhere else. Pervious surfaces include both greenspace, such as private lawns, city parks, gardens, or unpaved lots, and areas of gravel or pavement made from permeable materials such as pervious concrete or pervious brick pavers. Green roofs, which can absorb and retain stormwater and decrease rooftop runoff, are also a type of pervious surface. The focus of this section of the BEQI report is living, green infrastructure, but in areas that must be paved, permeable pavement can help substantially in mitigating stormwater runoff.

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[12] Ibid.

[13] Eason, C.T., J.E. Dixon, & M.R. van Roon. 2009. A trans-disciplinary research approach providing a platform for improved urban design, quality of life and biodiverse urban ecosystems. p.470-483. In: McDonnell, M.J., A.K. Hahs, & J.H. Breuste (eds.) *Ecology of Cities and Towns: A Comparative Approach*, Cambridge, UK, Cambridge University Press, 714pp.

[14]([EPA) U.S. Environmental Protection Agency. 2007. Reducing stormwater costs through Low Impact Development (LID) strategies and practices. EPA 841-F-07-006. Washington, D.C.: United States Environmental Protection Agency, Nonpoint Source Control Branch. Online available at http://water.epa.gov/polwaste/green/upload/2008_01_02_NPS_lid_costs07uments_reducingstormwatercosts-2.pdf. Last accessed 13 Jul 2011.

[15] Ibid.

[16] Eason et al. 2009; Van der Ree, R. 2009. The ecology of roads in urban and urbanizing landscapes. p.185-196. In: McDonnell, M.J., A.K. Hahs, & J.H. Breuste (eds.) *Ecology of Cities and Towns: A Comparative Approach*, Cambridge, UK, Cambridge University Press, 714pp.

[17] See EPA's Office of Stormwater website for more information on combined sewer overflows: http://cfpub.epa.gov/npdes/home.cfm?program_id=5.

2. A second type of green infrastructure that helps decrease stormwater runoff is the urban forest. During rainstorms, the leaves and branches of large trees growing in urban areas intercept rainfall and delay the amount of time it takes for the water to reach the ground and flow into the storm sewer system. In this way, trees decrease the peak load of water entering a city's storm sewer system. The trees also absorb some of the water that falls onto them and give some of the water on their surface time to evaporate before it can trickle down to the ground. Trees therefore decrease the total amount of water that does ultimately reach the ground. Street trees can provide substantial stormwater benefits to a city. For instance, it is estimated that street trees in Indiana's cities provide more than $24 million in stormwater benefits annually.[18]

3. Lastly, the plants in green infrastructure structures such as bioswales, rain gardens, detention ponds, and other forms of natural landscaping can help not only absorb stormwater, but filter out the pollutants and contaminants in urban runoff before the water reaches groundwater systems or surface water features, such as streams rivers and lakes. Bioswales and rain gardens work by directing stormwater into low-lying areas of vegetation where plants can trap sediment and filter pollutants out from stormwater runoff. Detention ponds with native, water-loving plants work similarly to bioswales and rain gardens but are designed to hold larger amounts of water for longer periods of time. In lawns or gardens, areas vegetated with native plants generally allow stormwater to drain back into the ground much more effectively than areas vegetated with turf grass.[19]

Stormwater management and green infrastructure in Bloomington

The City of Bloomington is actively using a variety of types of green infrastructure to mitigate stormwater runoff. Bloomington has chosen the following indicators to illustrate how green infrastructure is used in our city to manage stormwater.[20] (Note that the indicators presented below are not meant to illustrate total city performance on stormwater management, but are meant to reflect green infrastructure related to stormwater. For more on city stormwater management and programs, please see the City of Bloomington Utilities webpage. (For a complete list of all indicators for all categories, click here):

- **Indicator #1a: Percent of street tree spaces filled.** Street trees, like all trees, help slow the amount of rainwater that reaches the ground during a storm, decreasing runoff to storm sewers. The greater the percentage of filled street tree spaces, the better the urban forest intercepts stormwater, which serves to decrease runoff and the frequency and severity of combined sewer overflows.
- **Indicator #1b: Percent of street trees that are large/mature (>18" in diameter).** Large/mature trees, with a diameter of greater than 18 inches and a tree canopy frequently of greater than 40 feet in diameter, intercept stormwater better than smaller diameter trees with a correspondingly smaller canopy.
- **Indicator #4a: Number (and percent) of new developments (since 2001) using methods of biofiltration (i.e. bioswale, rain garden, detention pond native plants).** Biofiltration features within urban

[18] Indiana Urban Forest Council. 2008. *Urban Trees: The Ultimate Stormwater Treatment Plant.* The Sample Urban Statewide Inventory (SUSI) Fact Sheets. Online available from http://iufc.org/media/susiStormwater.pdf.
[19] Van der Ree 2009.
[20] A note on all Green Infrastructure Indicators: The City of Bloomington Environmental Commission recognizes that the indicators chosen for each ecosystem service are more directly indicative of the green infrastructure features themselves, rather than actually measuring the service provided by the green infrastructure. Although many attempts have been made to put measured values on urban ecosystem services (e.g., meals of food provided by urban gardens, tons of carbon sequestered by the urban forest, gallons of stormwater intercepted by street trees, dollar-increase in property values resulting from living ½-mile from a city park, etc.), we have elected to instead portray the physical entities of green infrastructure as our indicators (e.g., numbers of gardens, trees, or native plantings), believing that these can be more easily observed by individuals in Bloomington. Additionally, there are many problems with the abstraction that results from use of valuation methods to calculate, for instance, gallons of stormwater intercepted by street trees, or dollar-increase in property values due to the proximity of green infrastructure. Values calculated from models or equations are highly sensitive to the structure of the model and the values of parameters with which it was created. Thus, in the interest of clarity and of avoiding controversy, we choose to track indicators that can be easily measured and observed on the ground.

developments help not only slow surface runoff originating from roads and rooftops, but also enable pollutants and sediment to be filtered out of the rainwater and runoff before it drains into local water features.

- **Indicator #4d: Number of developments with green roofs.** Vegetation on green roofs can intercept and absorb stormwater, which reduces rooftop runoff.
- **Indicator #5b: Number of public facilities using stormwater biofiltration.** As mentioned above, biofiltration slows surface runoff and filters pollutants from stormwater.

How does Bloomington measure up on these indicators?

The following table tells us how Bloomington stacks up on each of the above indicators related to managing stormwater with green infrastructure. (For a complete list of all indicators for all categories, click here.)

Green Infrastructure Indicator	Value *	Last update
#1a: Percent of street tree spaces filled.	75% [a]	2007
#1b: Percent of street trees that are large/mature (>18" in diameter).	17% [a]	2007
#4a: Number (and percent) of new developments (since 2001) using methods of biofiltration (i.e. bioswale, rain garden, detention pond native plants).	18 (11%) [l]	2011
#4d: Number of developments with green roofs.	3 [l]	2011
#5b: Number of public facilities using stormwater biofiltration.	6 [p]	2012

* *Footnotes on values in table indicate the source of the information for the indicator:*

[a] Fischer, B.C., M. Steinhoff, S. Mincey, & L. Dye. 2007. The 2007 Bloomington Street Tree Report: An Analysis of Demographics and Ecosystem Services. Bloomington Urban Forestry Report 01-07. Available at http://bloomington.in.gov/media/media/application/pdf/2337.pdf.

[l] The City of Bloomington Planning Department. Environmental Agreements of Developments Database.

[p] Visited www.greenspots.in and spoke with Mike Hicks, Capital Projects Manager, City of Bloomington Utilities, 25 June 2012 and Steve Cotter, Natural Resources Manager, City of Bloomington Parks and Recreation, 2 July 2012. Note: Utilities Department Administrative Office Building, located on 600 E. Miller Drive, has pervious pavement, rain gardens, a bioswale with native plantings. Miller-Showers Park, located on 1500 N. College Avenue, has large detention ponds that retain storm water draining from over 170 acres of downtown Bloomington. Griffy Lake Nature Preserve, located at 3300 N. Headley Road, has 2 rain gardens filtering runoff from parking area before it enters the lake. Lower Cascades Park has a pervious pavement parking lot. Bryan Park has a native riparian buffer along its creek. The Goat Farm located along the Jackson Creek Trail near the Sherwood Oaks Park has a native riparian buffer along Jackson Creek and in the floodplain.

ECOSYSTEM SERVICE #2: INCREASED BUSINESS AND HOME VALUES

In addition to helping decrease stormwater management costs for a city, green infrastructure can also increase business and home values. Greenspace of all kinds, such as parks, urban woodlands, gardens, street trees, and yard trees can all increase property values for businesses and homeowners. People are attracted to the aesthetic that a treed street or neighborhood provides, and are often willing to pay a premium for this.[21] Houses adjacent to parks or open spaces typically command a price between 5 and 20% higher than homes not adjacent to these amenities.[22] Not all types of parks or open spaces are valued equally by homeowners, however. For instance, parks consisting mostly of flat, grassy open areas and recreational fields are valued less than parks with more 'natural' areas that include woodlands, hills and valleys, or water features, such as ponds or wetlands. More complex natural areas result in a higher premium paid for nearby properties.[23]

Individual yard and street trees can also increase residential property values. In new developments where builders have taken care to preserve existing mature trees or small forest patches, homes sell for higher prices than in developments where no mature trees were preserved.[24] Table 1 summarizes some observed price increases for homes in residential areas based on various green infrastructure situations.

Table 1. Potential percent price increases for preservation, installation, and/or maintenance of green infrastructure in residential developments in cities. [*Source:* Information adapted from Wolf, K.L. 2010. Urban Ecosystem Services: Metro Nature and Human Well-Being. In: Laband, D.N. (ed.), Linking Science and Society, Proceedings of Emerging Issues along Urban/Rural Interfaces III, Aug 2010, Atlanta, GA. [Online] Last accessed 13 Jul 2011. Available here. See this source for a complete list of research that produced these estimates.

Potential % price increase	Green infrastructure
3-5%	Trees included in front yard landscaping
10-15%	Mature yard and street trees in a high-income neighborhood
18%	Building lots (no house) with ample mature tree cover
19-35%	House on lot bordering a wooded preserve in a suburban area
32%	Houses in residential developments adjacent to greenways/greenbelts
10%	Inner-city house located within ¼ mile of a park OR within 2-3 blocks of a heavily used recreational park
8%	Home with a view of a park
4-5%	Apartment or condo in multifamily building with a view of a forested area

In addition to increased real estate value for residential properties, business owners in heavily treed commercial centers or business districts (Figure 1) can also experience increased shopper spending at their businesses. Work by Kathleen Wolf, a researcher at the College of Forest Resources of the University of Washington has revealed that on average, shoppers in small city retail districts are willing to spend more money per item in districts with trees compared to those without.[25] In addition to increased

[21] See the following source for a simple explanation of how researchers determine the contribution of green infrastructure to home and property values: Wolf, K.L. 2010. Urban Ecosystem Services: Metro Nature and Human Well-Being. In: Laband, D.N. (ed.), Linking Science and Society, Proceedings of Emerging Issues along Urban/Rural Interfaces III, Aug 2010, Atlanta, GA. Online available at http://www.naturewithin.info/CivicEco/InterfacesIII%20Prcdngs_HHWB%20Urban%20Eco%20Services.Dec2010.pdf. Last accessed 13 Jul 2011.

[22] Crompton, J.L. 2001a. *Parks and Economic Development*. PAS Report No. 502. Chicago, IL: American Planning Association.

[23] Crompton, J.L. 2001b. The impact of parks on property values: A review of the empirical evidence. *Journal of Leisure Research*, 33(1): 1-31.

[24] Wolf, K.L. 2010. Urban Ecosystem Services: Metro Nature and Human Well-Being. In: Laband, D.N. (ed.), Linking Science and Society, Proceedings of Emerging Issues along Urban/Rural Interfaces III, Aug 2010, Atlanta, GA. Online available at http://www.naturewithin.info/CivicEco/InterfacesIII%20Prcdngs_HHWB%20Urban%20Eco%20Services.Dec2010.pdf. Last accessed 13 Jul 2011.

[25] Wolf, K.L. 2005a. Trees in the Small City Retail Business District: Comparing Resident and Visitor Perceptions. *Journal of Forestry*, 103(8): 390-395.

spending once at a business, Wolf also found that consumers would travel longer times and greater distances to reach shopping districts with trees, and stay longer in these shopping districts once they arrived.[26] In larger cities, shoppers visiting central business districts were more willing to pay for parking in districts with large shade trees compared to districts without trees or vegetation.[27] In both small and large cities, residents and visitors preferred treed streetscapes, and perceived a more pleasant shopping experience there.[28] (For more research on the impacts of green infrastructure on local economies, see the "Green Cities: Good Health" website, sponsored by the University of Washington and the US Forest Service Urban & Community Forestry Program).

Figure 1. Trees and vegetation along business district streetscapes both improve the aesthetic appeal and cool the physical environment, potentially making people more likely to want to spend time in the retail district. (*Image source:* Wolf, K.L. 2009. Trees Mean Business: City trees and the Retail Streetscape. *Main Street News,* 263: 1-9).

Related research in commercial settings has shown that nature or greenery in retail areas can lift the mood of shoppers and reduce any stress that may be associated with the shopping experience (e.g., stress caused by the attempt to find a specific good under constrained time and budgetary resources).[29] By providing a green/natural "shopping environment" that alleviates customer stress, retailers are likely to see shoppers willing to spend both more time and money in their store.[30] Natural elements and vegetation within and around shopping environments can provide consumers a rest from the "Directed Attention Fatigue" that can result from information and sensory overload occurring in a busy store, and also may decrease instances of "purchase postponement" resulting from this fatigue.[31] In this way, green infrastructure such as street trees and landscaping around storefronts, can contribute to an improved consumer experience and more profitable in business districts.

[26] Wolf 2005a.
[27] Wolf, K.L. 2005b. Business District Streetscapes, Trees, and Consumer Response. *Journal of Forestry*, 103(8): 396-400.
[28] Wolf 2005a, 2005b.
[29] Joye, Y., K. Willems, M.Brengman, & K. Wolf. 2010. The effects of urban retail greenery on consumer experience: Reviewing the evidence from a restorative perspective. *Urban Forestry & Urban Greening,* 9: 57-64.
[30] Joye et al. 2010.
[31] Joye et al. 2010.

Business and home values and green infrastructure in Bloomington

The City of Bloomington likely benefits from increased business and home values as a result of our substantial green infrastructure. Bloomington is recognized for our investment in and care for our urban forest by the Arbor Day Foundation as a Tree City USA. To track how well we are doing in improving our green infrastructure in order to increase business and home values, the following Indicators of green infrastructure have been chosen. (For a complete list of all indicators for all categories, click here):

- **Indicator #1b: Percent of street trees that are large/mature (>18" in diameter).** Large, mature street trees make a neighborhood or business district look more aesthetically appealing, thus increasing the value homeowners, renters, or businesses are willing to pay to reside there.
- **Indicator #1c: Percent of street trees that are young (<6" in diameter).** Young street trees do not directly increase the value of a home or business, but do ensure the existence of a replacement population of street trees to replace the large/mature trees when they reach the end of their urban life. This ensures that the home and business values will not drop suddenly if a storm or insect invasion causes all the old mature trees to become ill.
- **Indicator #1f: Ratio of the number of trees planted to the number removed per year.** In order for trees to continue to provide value to the homeowner or business owner, a sustainable tree population (that is either remaining stable or expanding in number of trees) must exist.
- **Indicator #1g: Tree City USA status and Tree City Growth Award secured yearly.** Tree City USA status is an indication of investment at the City level in the urban forest and the benefits it provides like increased business and home values. The Tree City award requires that a city have a tree ordinance, an annual Arbor Day celebration, a tree board or commission, and spend at least $2 per capita on the urban forest. The Tree City Growth Award indicates a desire to increase City commitment to the urban forest.
- **Indicator #5a: Number (and area) of public parks in Bloomington.** Because home values are higher adjacent to, and in the vicinity of, public parks, the number and area of city parks located in Bloomington is important to increasing local home values.

How does Bloomington measure up on these indicators?

The following table tells us how Bloomington stacks up on each of the above indicators of green infrastructure related to business and home values. (For a complete list of all indicators for all categories, click here.)

Green Infrastructure Indicator	Value *	Last update
#1b: Percent of street trees that are large/mature (>18" in diameter).	17% [a]	2007
#1c: Percent of street trees that are young (<6" in diameter).	26.7% [a]	2007
#1f: Ratio of number of trees planted to number removed per year.	388:125 [b]	2009
#1g: Tree City USA status and Tree City Growth Award secured yearly.	YES and NO [b]	2010
#5a: Number (and area) of public parks in Bloomington.	26 (214.02 acres) [o]	2012

* *Footnotes on values in table indicate the source of the information for the indicator:*

[a] Fischer, B.C., M. Steinhoff, S. Mincey, & L. Dye. 2007. The 2007 Bloomington Street Tree Report: An Analysis of Demographics and Ecosystem Services. Bloomington Urban Forestry Report 01-07. Available at http://bloomington.in.gov/media/media/application/pdf/2337.pdf.

[b] Tree City USA data obtained from P. Louks, Community & Urban Forestry Coordinator, Indiana Department of Natural Resources, personal communication, 12 February 2010

[o] Acreage Inventory data obtained from Dave Williams, City of Bloomington Parks & Recreation Department, 08 June 2012. Note: only based on "developed" acreage in Broadview Park, Bryan Park, Building & Trades Park, Upper and Lower Cascades Park, Crestmont Park, Ferguson Park, Griffy Lake Nature Preserve, Highland Village Park, Leonard Springs Nature Park, Maple Heights Park, Miller-Showers Park, Olcott Park, Park Ridge Park, Park Ridge East Park, Peoples Park, RCA Community Park, Reverend Butler Park, Schmalz Farm Park, Seminary Park, Sherwood Oaks Park, Southeast Park, and Third Street Park.

ECOSYSTEM SERVICE #3: DECREASED URBAN HEAT ISLAND (UHI) EFFECTS

The many facets of urbanization in cities and towns result in higher temperatures in these areas than surrounding rural areas. This effect is called the urban heat island (UHI). The urban heat island is defined as *"those urban areas where the surface, sub-surface or air temperatures are higher than the corresponding temperatures in surrounding rural areas."*[32] The overall UHI effect results from the same processes that influence temperatures in rural areas – processes that are affected by land cover type, local moisture regimes, albedo, radiant heat, and a host of other factors.[33] [34] Elevated temperatures in urban areas specifically are caused by various factors: the decreased ability of urban areas to experience evaporative cooling (because of a decrease in vegetation, and an increase in runoff due to increased impervious surfaces), increased heat absorption by urban areas (due to a decrease in reflectivity, or albedo, and the subsequent increase in heat radiated from heat-absorbent surfaces), and an increase in waste heat produced by cars, buildings, etc. (see Figure 1).[35]

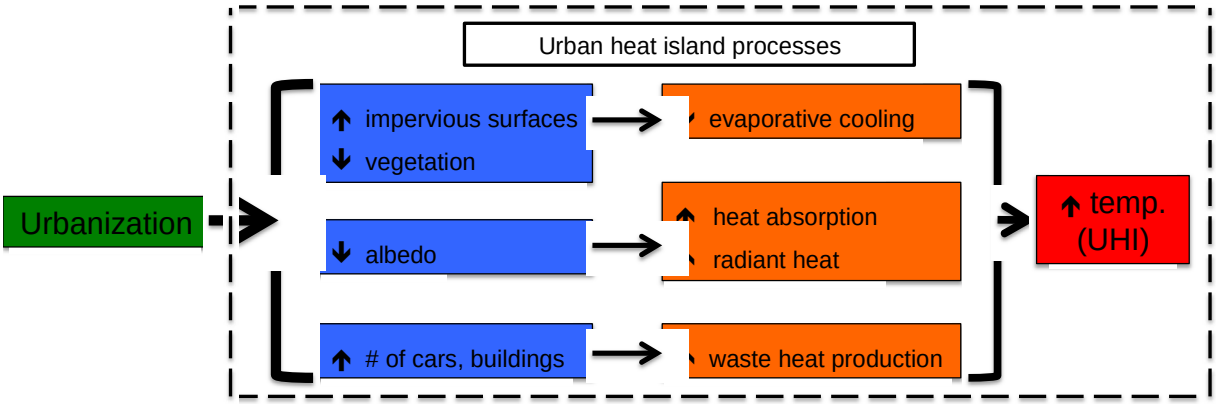

Figure 1. Simplified model of the processes driving the increased temperatures resulting from the UHI effects.

The UHI can result in an average annual air temperature differential (increase in the temperature of urban areas over that of adjacent rural areas) of 1.8 to 5.4 °F (1 to 3 °C) and as much as 12.6 to 21.6 °F (7 to 12 °C) during summer evenings.[36] The urban heat island effect increases in magnitude with increasing city size, but even smaller cities and towns have some increase in temperatures relative to surrounding rural areas.

There are two components of the urban heat island impact: surface temperature changes and atmospheric temperature changes. The UHI effect can raise temperatures both on the surface and in the atmosphere above urban areas, but surface temperatures exhibit greater variability, both between surfaces (e.g., at a dark asphalt road surface compared to white roof surface), from day to night, and between rural and urban

[32] Alcoforado, M.J. & H. Andrade. 2008. Global Warming and the Urban Heat Island. p.249-262. In: Marzluff, J.M., G. Bradley, E. Shulenberger, C. Ryan, W. Endlicher, U. Simon, M. Alberti, & C. ZumBrunnen (eds.), *Urban ecology: An international perspective on the interaction between humans and nature*, New York, Springer. p. 250.
[33] Kurn, D.M., S.E. Bretz, B. Huang, & H. Akbari. 1994. *The potential for reducing urban air temperatures and energy consumption through vegetative cooling.* Pacific Grove, CA: American Council for an Energy Efficient Economy Summer Study on Energy Efficiency in Buildings. 31pp. Online available at http://www.epa.gov/heatisland/mitigation/trees.htm. Last accessed 8 May 2011
[34] Arnfield, A.J. 2002. Two decades of urban climate research: A review of turbulence, exchanges of energy and water, and the urban heat island. *International Journal of Climatology*, 23: 1-26; Alcoforado & Andrade 2008.
[35] Kurn, et al. 1994; Arnfield 2002; Alcoforado & Andrade 2008; (EPA) U.S. Environmental Protection Agency. 2008a. Reducing Urban Heat Islands: Compendium of Strategies. Washington, D.C.: United States Environmental Protection Agency, Office of Atmospheric Programs. Online available at http://www.epa.gov/heatisland/resources/compendium.htm. Last accessed 9 Apr 2011.
[36] EPA 2008a.

areas, compared to the atmospheric temperature changes due to the UHI (see Figure 2).[37] This is due to the greater mixing of air that occurs in the atmosphere relative to the ground, resulting in relatively homogenous atmospheric air temperature increases throughout an urban area. Differences in air temperature within the city tend to be more closely linked with distance from the ground than with horizontal features; for instance, the canopy-level (from ground-level to the tops of buildings and trees) experiences greater temperature differentials than the boundary layer of atmosphere (above the tops of buildings and trees, where air is more well-mixed.[38] The unique characteristics of surface-level and atmospheric UHI effects have important implications for how vegetation can be used to mitigate those effects.

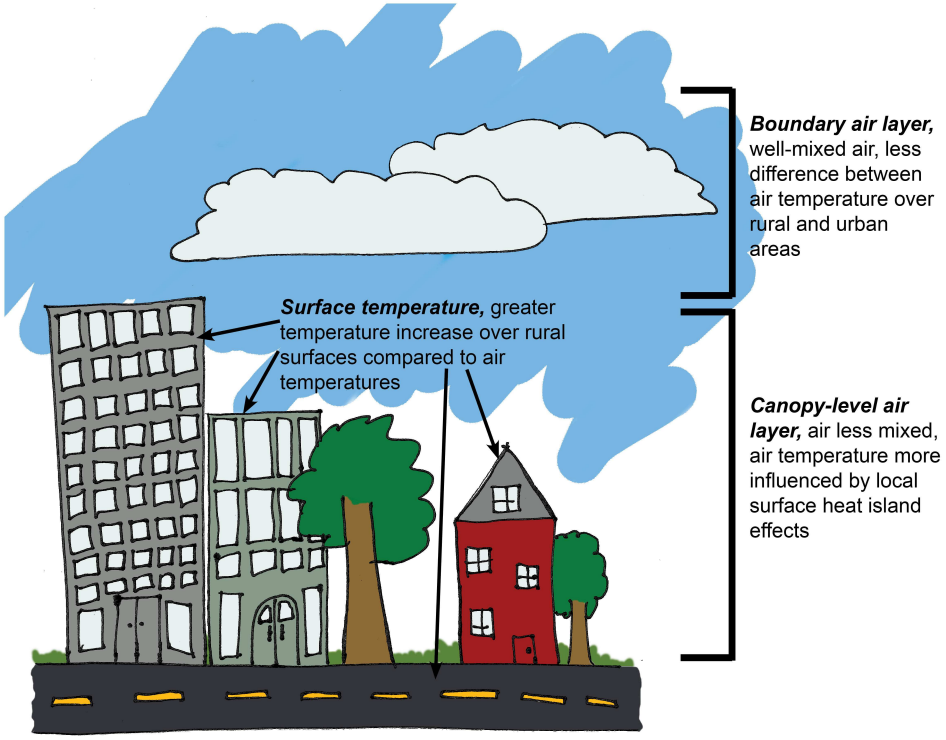

Figure 2. Relative temperature differentials at the surface and canopy-level and boundary layer air, resulting from urban heat island effects. Temperatures on urban surfaces (building walls and roofs, roads, etc.) are much greater compared to rural surfaces (grass and forests outside of urban areas). Canopy-level air temperatures (between the ground and the tops of buildings) are slightly greater than canopy-level air temperatures in forests outside urban areas; while, boundary layer air temperatures (above the tops of buildings and trees) are only slightly higher than boundary layer temperatures in non-urban areas, due to the greater mixing of the air occurring in the absence of obstacles. (*Figure design:* J.M. Vogt.)

[37] EPA 2008a
[38] EPA 2008a

Vegetation and green infrastructure moderates the effect of the urban heat island through three major pathways: direct shading, evapotranspiration, and the urban breeze cycle (see Figure 3).[39] Vegetation – particularly large trees – shades and cools the surface temperature by preventing 70-90% the sun's energy from reaching the area beneath trees and vegetation.[40] Surfaces shaded by vegetation may be up to 20-45° F (11-25° C) cooler than the surrounding un-shaded surfaces.[41] You can feel this difference every time you walk under the shade of a tree after being in the sun, or park your car in a shaded spot in the parking lot. This decreased surface temperature reduces heat transmitted to buildings and air surrounding shaded surfaces, further mitigating UHI effects.[42]

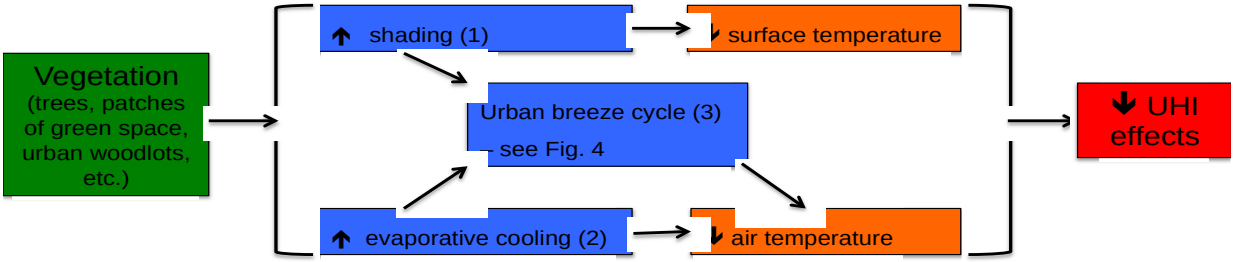

Figure 3. Vegetation mitigates the urban heat island (UHI) via three pathways: (1) shading, (2) evaporative cooling, and (3) the urban breeze cycle. (For a detailed version of the urban breeze cycle, see Figure 4.)

Any vegetation planted in cities increases the evapotranspiration capacity of the city. Evapotranspiration helps dissipate heat energy trapped by the UHI. Plants absorb water via their roots (transpiration) and transfer the water to its leaves, which then evaporate water through the pores in the leaves. Water also evaporates from the soil surrounding the vegetation. In both instances, water evaporating from soil and the leaves of plants uses energy obtained from heat in the air, thereby decreasing local temperatures. Humans experience this same cooling process when sweat evaporates off their bodies. Vegetative patches or individual trees in cities can cumulatively have a large impact on increasing the amount of heat dissipated through evapotranspiration.[43]

The urban breeze cycle of cities also influences the effect vegetation has on the UHI (Figure 4). Warm air is lighter and less dense than cooler air. Warm air created in cities rises, spreads out, and eventually cools and sinks over non-urban areas. Because this cool air in rural areas is of higher atmospheric pressure than the warm air in cities, the cool air flows back into the city, moving as wind from an area of high pressure to an area of low pressure. The influx of cool non-urban air displaces more warm urban air, which once again rises, spreads out, and cools.[44] Research has demonstrated that air temperatures in less developed areas abutting urban areas are between 2 and 9° F (1 and 5° C) cooler than open or bare areas (Table 1)[45]. Proper vegetation located around the periphery of cities can enhance the cooling effects of the urban breeze cycle because the vegetation will further cool the air being blown back into urban areas, thus reducing urban temperatures and UHI effects. The urban breeze cycle can also create cooling effects on a

[39] (APA) America Planning Association. 2007. *How cities use parks for climate change management,* City Parks Forum Briefing Papers. Chicago, IL: American Planning Association. 4pp. Online available at http://www.planning.org/cityparks/briefingpapers/climatechange.htm. Last accessed 2 Apr 2011.
[40] EPA 2008a.
[41] U.S. Environmental Protection Agency (EPA). "Heat Island Effect." Online available at http://www.epa.gov/heatisland/. Last accessed 10 Oct 2012.
[42] EPA 2008a.
[43] EPA 2008a.
[44] APA 2007.
[45] EPA 2008a.

micro-scale. If patches of vegetated greenspace are located throughout a city, air can be cooled on a smaller scale within the city itself.

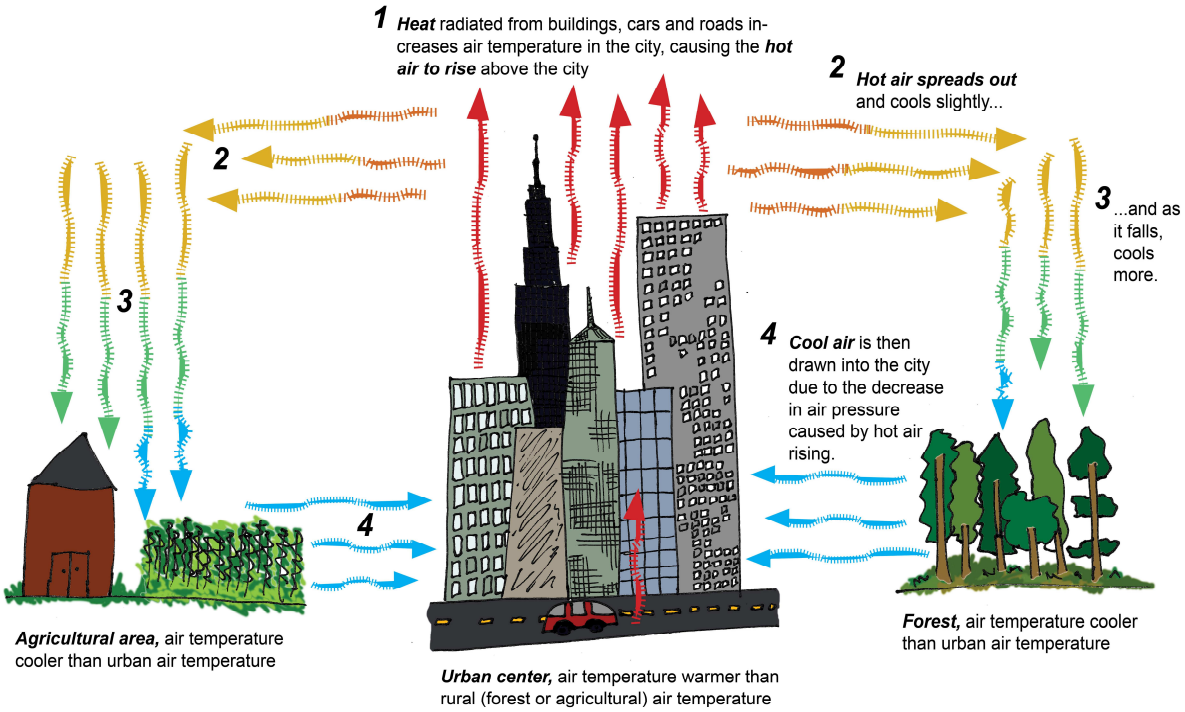

Figure 4. Urban breeze cycle. (**1**) Warm air from the center of an urban area rises and **(2)** spreads out above the city, naturally cooling and becoming denser as it does so. **(3)** This cool, dense air then sinks into adjacent areas, creating an atmospheric pressure differential between the city and surrounding rural areas that **(4)** draws the cool air from the adjacent areas back into the city. The cooler the air in the adjacent areas, the greater the cooling effect on the city when that air moves back into the urban center. This cycle can also occur at much smaller scales within the city itself. [*Source:* Information from: America Planning Association. 2007. *How cities use parks for climate change management,* City Parks Forum Briefing Papers. Chicago, IL: American Planning Association. 4pp. [Online] Available at http://www.planning.org/cityparks/briefingpapers/climatechange.htm. Last accessed 2 Apr 2011. *Figure design:* J.M. Vogt.]

Table 1. Comparison of temperatures in areas potentially adjacent to urban areas. These land cover types could be the source of cool air drawn into the city by the urban breeze cycle. [*Source:* Adapted from U.S. Environmental Protection Agency. 2008a. Reducing Urban Heat Islands: Compendium of Strategies. Washington, D.C.: United States Environmental Protection Agency, Office of Atmospheric Programs. Online available at http://www.epa.gov/heatisland/resources/compendium.htm. Last accessed 9 Apr 2011.]

Land cover type…	…is…degrees cooler than…	…reference land cover type
Forested areas and woodlots	9°F (5°C)	Open terrain (meadow, etc.)
Agricultural fields (irrigated)	6°F (3°C)	Bare ground
Suburban area w/ mature trees	4-6°F (2-3°C)	Suburban area w/o trees
Grass sports fields	2-4°F (1-2°C)	Bare ground

Urban heat island effects and green infrastructure in Bloomington

Green infrastructure, ranging from single trees to entire parks, can help mitigate the UHI effects. The City of Bloomington has chosen the following indicators to track several types of our green infrastructure that relate to reducing the UHI. (For a complete list of all indicators for all categories, click here):

- **Indicator #1b: Percent of street trees that are large/mature.** Street trees reduce local temperatures by shading houses, buildings, streets and yards and also through evapotranspiration.
- **Indicator #1f: Ratio of the number of trees planted to the number removed per year.** In order to ensure mitigation of the urban heat island into the future, we must plant more trees than we remove each year; otherwise, the loss of trees will result in an increasing temperature differential.
- **Indicator #4c: Number (and area) of "conservancy easements," as defined by the City Unified Developments Ordinance (UDO) and dedicated by developers.** The urban breeze cycle operates on a micro-scale in a similar fashion as the city-scale cycle described above (Figure 3). Thus, patches of undisturbed vegetation within urban developments can help cool local temperatures.
- **Indicator #5a: Number (and area) of public parks in Bloomington.** Not only do parks also contribute to local cooling via the urban breeze cycle, but they also provide a comfortable refuge for city residents to go to in order to escape the increased temperatures of the city resulting from the UHI effect.
- **Indicator #6a: Number (and area) of conservation easements owned by nonprofits or government agencies.** Official conservation easements can also influence the micro-scale urban breeze cycle and help cool local temperatures. Conservation easements (including the agricultural easements) on the outskirts of a city can help ensure that the air brought into a city through city-scale urban breeze cycle is cool.
- **Indicator #6b: Percent (and area) of total greenspace in Bloomington.** Greenspace, as discussed above, has both local cooling effects, via direct shading and evapotranspiration, as well as city-level cooling effect through the urban breeze cycle effects.

How does Bloomington measure up on these indicators?

The following table tells us how Bloomington stacks up on each of the above indicators related to decreasing the urban heat island effect using green infrastructure. (For a complete list of all indicators for all categories, click here.)

Green Infrastructure Indicator	Value *	Last update
#1b: Percent of street trees that are large/mature (>18" in diameter).	17% [a]	2007
#1f: Ratio of the number of trees planted to number removed per year.	388:125 [b]	2007
#4c: Number (and area) of "conservancy easements," as defined by the City Unified Development Ordinance (UDO) and dedicated by developers.	10 (79.107 acres) [m]	2008
#5a: Number (and area) of public parks in Bloomington.	26 (214.02 acres) [o]	2012
#6a: Number (and area) of conservation easements owned by nonprofits or government agencies.	4 (266.2 acres) [q]	2012
#6b: Percent (and area) of total greenspace in Bloomington.	38.5% (6,429.3 acres) [r]	2007

[*] *Footnotes on values in table indicate the source of the information for the indicator:*

[a] Fischer, B.C., M. Steinhoff, S. Mincey, & L. Dye. 2007. The 2007 Bloomington Street Tree Report: An Analysis of Demographics and Ecosystem Services. Bloomington Urban Forestry Report 01-07. Available at http://bloomington.in.gov/media/media/application/pdf/2337.pdf.

[b] Tree City USA data obtained from P. Louks, Community & Urban Forestry Coordinator, Indiana Department of Natural Resources, personal communication, 12 February 2010

[m] Linda Thompson, City of Bloomington Planning Department, "Conservancy Easements Database", 24 August 2012. Addresses (area): 2401 W. Tapp Road (59 acres); 3600 N. Prow Road (acres N/A); 3201 S. Wickens Street (acres N/A); 2310 W. 3rd Street (acres N/A); 1300 W. Countryside Lane (1.057 acres); 1201 S. Smith Road (acres N/A); 751 E. Tamarack Trail (1.78 acres); 2107 W. 3rd Street (17.27 acres); 3111 S. Walnut Street Pike (acres N/A); 2410 E. Moores Pike (acres N/A).

[o] Acreage Inventory data obtained from Dave Williams, City of Bloomington Parks & Recreation Department, 08 June 2012. Note: only based on "developed" acreage in Broadview Park, Bryan Park, Building & Trades Park, Upper and Lower Cascades Park, Crestmont Park, Ferguson Park, Griffy Lake Nature Preserve, Highland Village Park, Leonard Springs Nature Park, Maple Heights Park, Miller-Showers Park, Olcott Park, Park Ridge Park, Park Ridge East Park, Peoples Park, RCA Community Park, Reverend Butler Park, Schmalz Farm Park, Seminary Park, Sherwood Oaks Park, Southeast Park, and Third Street Park.

[q] 1. Sycamore Land Trust holds two conservation easements within Bloomington city limits. One is 16 acres on Lot 1 and Lot 2 of the Sakes Tarzian Subdivision. The county assessor's property cards list the addresses for these lots as 1113 E. Hillside Drive and 1020 S. Highland Avenue. The easement was recorded as instrument #2002007421 on 4/1/2002 and rerecorded as instrument #2012003734 on 3/9/2012. The other easement is about 0.2 acres, covering the south half of Lots 9 and 10 of the Allendale Addition. The property address is 717 S. Henderson Street. The easement was recorded as instrument #2002030757 on 12/19/2002. (John Lawrence, Assistant Director of Sycamore Land Trust, personal communication, 20 June 2012). 2. Bloomington Parks and Recreation holds two parcels at Griffy Lake that have official conservation easements: the original state-dedicated Griffy Woods Nature Preserve, which included 240 acres, and the 10-acre Schneider property, which was added to the state-dedicated preserve. (Steve Cotter, Natural Resources Manager, Bloomington Parks and Recreation).

[r] City of Bloomington Environmental Commission & C. Winkle. 2007. Greenspace trends in Bloomington, Indiana 1993-2007. City of Bloomington, Indiana. 11pp. Online available at https://bloomington.in.gov/media/media/application/pdf/2738.pdf. Last accessed 30 June 2011.

ECOSYSTEM SERVICE #4: FOOD FROM URBAN AGRICULTURE

At its simplest, urban agriculture can be defined as "the growing of plants and the raising of animals within and around cities."[46] Food production is usually the primary goal of urban farmers, but people may also practice urban agriculture as a means of producing non-food products such as straw or wool. The products from urban agriculture may be grown for personal consumption, commercial sale, charitable donation, or some combination of those options. Urban agriculture can range in scale from a full-scale farm to a single basil plant on your windowsill. The theme uniting all these different variations of urban agriculture is location. Urban agriculture, unlike agriculture in rural areas, is integrated directly into a town or city's economic and ecological system[47]. This fact presents urban growers with many exciting opportunities for innovation.

Urban agriculture is for everyone. Individuals as well as groups in the public, private, and non-profit sectors can all take part in greening their cities and turning local food deserts into greenspaces capable of producing bountiful harvests. Gardening can take the form of backyard gardens, balcony gardens, garden towers, grow bags, greenhouses, edible landscaping, peri-urban farms, indoor potted plants, lasagna gardens, living plant walls, rooftop gardens, raised garden beds, vertical garden towers, and much more. Groups of people can work together to establish community orchards, community gardens, urban and peri-urban farms, and community supported agriculture (CSA) programs.

Many people in Bloomington are already actively involved in urban agriculture. Community garden plots are available to the public through the City of Bloomington's Parks and Recreation Department. Local food products can be bought and sold at the Bloomington Community Farmers' Market and though Bloomington's various Community Supported Agriculture programs. Gardening advice is available from the Bloomington Organic Gardeners, Indiana University's Hilltop Garden & Nature Center, the Monroe County Master Gardener Association, classes offered through the Department of Parks and Recreation, and the Bloomington Environmental Commission's natural landscaping page. Heirloom seed varieties grown in Indiana since the nineteenth century are cultivated and sold by the Wylie House Museum. Many local residents are also happy to share or trade seeds with fellow gardeners. Various local organizations promote urban agriculture, including the Bloomington Food Policy Council, Bloomington Garden Club, Bloomington Permaculture Guild, Bloomington Community Orchard, Hoosier Hills Food Bank, Local Growers Guild, Mother Hubbard's Cupboard, Slow Food Bloomington, and Transition Bloomington. Bloomington is also a center of academic interest in urban agriculture and is the first town in the world to host a PhD program in the anthropology of food.

[46] Resource Centres on Urban Agriculture and Food Security (RUAF) - http://www.ruaf.org/node/512/.
[47] Ibid.

Figure 1. Bloomington residents Meagan and Kristen Lukha with backyard chickens. City of Bloomington residents can currently raise five or fewer hens, as defined by the guidelines in Title 7 of the Municipal Code. Bloomington residents interested in raising chickens must first contact Animal Control and submit an application for a chicken flock permit.

Communities and individuals benefit from urban agriculture in many ways. Urban agriculture can provide:

• affordable or donated food supplies for lower-income people
• local economic vitality through the creation of green jobs, farmers' markets, crop-sharing programs, and Buy Local campaigns
• a foundation for community sustainability that helps address concerns over food safety and security
• increased feelings of personal empowerment and being connected to the environment
• improved health resulting from the physical exercise of gardening
• relaxation and stress reduction
• opportunities for community engagement, from volunteering to serving on the board of a local organization, that foster a greater sense of belonging and togetherness

Urban agriculture can be particularly beneficial for young people. Greenspace gives urban youth room to get outside and reconnect with nature. In addition, urban gardens can provide educational opportunities, starring as the location for active learning programs about math and science as well as a way to teach children about healthy eating.

Urban agriculture also promotes environmental stewardship. Urban farms can reduce the burden on municipal landfills by using a city's organic wastes for compost. In Bloomington, for example, food waste from Indiana University's Collins Living-Learning Center (a residence hall) is composted and used

to fertilize a garden plot managed by the student group SPROUTS (Students Practicing Organics under the Sun). Replacing synthetic fertilizers and toxic pesticides with organic horticulture methods in urban agriculture leads to improved local soil health and water quality, which in turn supports local plant and wildlife communities. Locally grown food also reduces the distance traveled by food from field to fork, thereby minimizing the packaging waste, energy consumption, and vehicle emissions associated with transporting what we eat.

Already an urban grower?

Consider reaching out the Bloomington community by supporting local philanthropic projects such as the Hooiser Hills Food Bank Plant-a-Row for the Hungry initiative.

Urban agriculture is important because the world's population is growing and is increasingly living in urban settings. With food safety and food scarcity concerns on the rise, urban agriculture is a way for citizens to educate themselves about where food comes from and work to integrate sustainable food production into the places they live. In short, being an urban agriculturalist is a fun way to make a real difference in the world and in your community.

No land? No excuse!

Bloomington apartment dwellers or other residents with limited space can still be involved with urban agriculture. Residents can grow plants indoors, rent a community garden plot, or volunteer with one of the many gardening projects around town, such as the Bloomington Community Orchard or Mother Hubbard's Cupboard.

Today, urban agriculture is becoming increasingly popular around the world, partially in response to several forces placing pressure on the global food system. The world's human population is growing exponentially and is living in urban areas more than ever before[48], creating increased demand for food as well as obstacles to transporting food grown in rural areas to where it is needed. In addition to food scarcity threats, concerns about food safety are also growing. To combat these issues, many are turning to urban agriculture. Recent food quality scandals in China, for example, have led thousands of Beijing residents to start growing their own vegetables in balcony gardens[49]. Urban gardens are also increasingly sprouting up in the disadvantaged areas of Africa and Latin America's cities[50], with and without the help of various non-profit and governmental organizations. Today's agricultural system may still rely largely on fossil fuels, synthetic chemical pesticides, and genetic modification, but local efforts are increasingly rallying international support for changes in how cities can incorporate sustainable agriculture and more security in the world's food system into urban planning.

In the future, urban agriculture sites may shift from being slipped into the cracks of the existing infrastructure of cities to being planned from the start as a core part of the urban planning process. Building vertical farms, both private and those filled with community garden plots, would be one potential strategy. The graphics below portray concept designs for vertical farming developments as rendered by some of the world's leading architects.[51] Though "farmscrapers" might be a stretch of the imagination for now, it is quite possible that these models or similar developments will become the future of urban agriculture sooner than expected. In the case of enclosed vertical farm, food could be grown

[48] United Nations Children's Fund (UNICEF). "The State of the World's Children 2012: Children in an Urban World." 2012. Available at http://www.unicef.org/sowc2012/index.php. Last accessed 17 September 2012.
[49] *China Daily*. "Balcony farmers are taking root." 25 June 2012. Available at http://www.chinadaily.com.cn/life/2012-06/25/content_15521007.htm. Last accessed 17 September 2012.
[50] Food and Agriculture Organization of the United Nations (FAO). "Urban farming against hunger: Safe, fresh food for city dwellers." Available at http://www.fao.org/newsroom/en/news/2007/1000484/index.html. Last accessed 17 September 2012.
[51] *Time*. "Urban Farming." Available at http://www.time.com/time/photogallery/0,29307,1825907,00.html. Last accessed 17 September 2012.

year-round in a totally controlled environment. No exposure to pests or disease would eliminate the need for pesticides.

Figures 2 and 3. Towers of Food, Models of Self-Sufficiency

Vertical farms, like these, would grow food closer to where it is consumed, thus eliminating much of the fuel and transportation costs. In the case of enclosed vertical farm, food could be grown year-round in a totally controlled environment. Vertical farms can also be designed to not require any water from municipalities and would use photovoltaic cells to produce nearly 100% of the building's electricity. (Images from *Time*.)

Home gardening and urban agriculture are not new ideas, however. In the United States during WII, victory gardens large and small were a common part of everyday life. According to the National World War II Museum, in 1944 victory gardens were responsible for producing 40% of all vegetables grown in the United States[52]. As part of a similar self-sufficiency initiative during WWI, President Woodrow Wilson even raised a flock of sheep on the lawn of the White House! The sheep's wool was auctioned off to raise money for the Red Cross[53]. After the World Wars, urban agriculture had a large resurgence in the United States during the 1970s as a way to use abandoned sites left in poor urban areas by the end of the postwar urban manufacturing boom[54]. While gardening can be a wonderful as purely a hobby, US history clearly shows that urban agriculture can also be a practical path to self-sufficiency and a way to rebuild community during times of crisis.

[52] The National World War II Museum. "Victory Gardens at a Glance." Available at http://www.nationalww2museum.org/learn/education/for-students/ww2-history/at-a-glance/victory-gardens.html. Last accessed 17 September 2012.
[53] The White House Historical Association. "*Why did President Woodrow Wilson keep a flock of sheep on the White House lawn?*" Available at http://www.whitehousehistory.org/whha_history/history_faqs-05.html. Last accessed 17 September 2012.
[54] Lawson, Laura. *City Bountiful: A Century of Community Gardening in America*. University of Californian Press. 2005.

Image 4: Vintage victory garden poster. Image from The Dinner Garden, a Texas-based non-profit that seeks to alleviate hunger in the United States by distributing free seeds to individuals wanting to start their own vegetable garden.

Urban agriculture is for everyone, regardless of their background or socioeconomic status. Contrary to a common misconception of urban gardens as "elitist," countless urban agriculture initiatives in the United States are focused on helping low-income communities help themselves by growing inexpensive, nutritious food and providing a safe place for community gatherings. One of the most celebrated urban agriculture projects to do this is Growing Power, a Milwaukee based organization started by former professional basketball player and MacArthur Foundation "Genius Grant" winner Will Allen. An offshoot of Growing Power, the Chicago Lights Urban Farm, works to provide food for the children and families living in Chicago's Cabrini-Green neighborhood. Similar organizations nationwide include Boston's The Food Project, Brooklyn's Added Value and East New York Farms, Las Vegas' Tonopah Community Garden, New York City's Just Food, Oakland's City Slicker Farms, and Washington DC's Common Good City Farm. As these organizations show, urban agriculture can be a powerful tool in working towards social justice.

Image 5: Growing Power's director Will Allen teaching urban gardening techniques to volunteers from the Milwaukee community. Image from Growing Power.

Have questions about urban agriculture in Bloomington?

Many questions can be answered by consulting Bloomington's Municipal Code. For inquiries about raising chickens in Bloomington, contact Animal Control. For questions relating to setback requirements and Bloomington's weed ordinance, contact the City's Planning Department.

Food from urban agriculture and green infrastructure in Bloomington

Green infrastructure, such as community orchards and garden plots, can improve local food security and safety. The City of Bloomington has chosen the following Indicators to track several types of our green infrastructure that relate to food from urban agriculture. (For a complete list of all indicators for all categories, click here):

- **Indicator #3a: Number (and area) of community garden plots.** The greater the number and size of community garden plots available, the more opportunities people in the community have to engage in gardening activities.
- **Indicator #3b: Number of community garden plot gardeners.** People who participate in community gardening not only build social capital, but they also decrease their risk of negative health effects resulting from isolation.
- **Indicator #3d: Number of trees in the Bloomington Community Orchard.** More trees in the Community Orchard, means more access to fresh, organic, and local food supplies.
- **Indicator #3e: Number of volunteers (to-date) at the Bloomington Community Orchard.** The number of volunteers at the Bloomington Community Orchard is an indication not only of social capital, but also of the amount of garden related activities occurring, thereby indirectly supportive of human health and well-being.

How does Bloomington measure up on these indicators?

The following table tells us how Bloomington fairs on each of the indicators of food from urban agriculture and green infrastructure. (For a complete list of all indicators for all categories, click here.)

Green Infrastructure Indicator	Value *	Last update
#3a: Number (and area) of community garden plots in Bloomington.	221 plots [h] 11.469 acres [h]	2012
#3b: Number of community garden plot gardeners	442 [h]	2012
#3d: Number of trees in the Bloomington Community Orchard.	75 [j]	2012
#3e: Number of volunteers (to date) at the Bloomington Community Orchard.	584 [j]	2012

[*] *Footnotes on values in table indicate the source of the information for the indicator:*

[h] Robin Hobson, Bloomington Parks & Recreation Department, personal communication, 14 September 2012.

- Indicator 3a underestimates the total number of community gardens in Bloomington because the indicators does not include neighborhood community gardens due to a lack of data.
- Rental plots in community gardens are available at two gardens run by the City of Bloomington Parks and Recreation Department: Willie Streeter and Butler Park. Willie Streeter Community Gardens is 1.26 acres in size and contains 180 rental plots, 122 of which are 200 ft^2 and 58 of which are 100 ft^2 (including 10 raised, accessible beds). Butler Park Community Gardens is 0.39 acres in size and contains 38 rental plots, 9 of which are 140 ft^2 and 29 of which are 95 ft^2.
- An average of two gardeners is assumed to use each rental plot available.
- Other community gardens in Bloomington that are managed as group projects add acreage to this indicator value but do not contain plots available for rental to individuals. Crestmont Park has 0 rental plots and totals 0.26 acres, Banneker Green Thumbs Garden has 0 rental plots and totals 0.041 acres, Harmony School Garden has 0 rental plots and totals 0.018 acres, Hilltop Garden and Nature Center has 0 rental plots and totals 5.0 acres, and the Permaculture Growers Co-Op has 3 rental plots and totals 4.5 acres.

[j] Amy Countryman, Bloomington Community Orchard, personal communication, 1 July 2012. Amanda Werhane, Bloomington Community Orchard, personal communication, 30 June 2012. Amy Allen, personal communication 28 September 2012. Volunteer numbers broken down by year: 2010: 195 volunteers; 2011: 374 volunteers; 2012 (January-June): 96 volunteers.

ECOSYSTEM SERVICE #5: HUMAN HEALTH AND WELL-BEING

For centuries, city dwellers looking to restore their physical and emotional health have sought out rural coasts, countryside, and forests in order to take in the fresh air and natural vistas.[55] Recent research indicates that city residents are more easily stressed than rural residents are and that individuals brought up in cities carry this stress with them throughout their lives, regardless of current living environment.[56] Greenspace in cities has the potential to ameliorate this stress, however, and help improve the well-being of urban residents.

The World Health Organization defines human health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."[57] Physical health implies that an individual is free from physiological disease and illness. Mental health is a multifaceted state that includes emotional stability and happiness as well as intellectual satisfaction. Social health implies the lack of isolation from others and the existence of healthy relationships with other people. Although it is widely asserted that socioeconomic and individual lifestyle factors are the largest drivers of individual health, environmental factors are increasingly becoming recognized as significant contributing factors.[58] The environmental features present where a person lives and works, such as amount of greenery visible through a window, or access to parks and other open spaces, can impact mental or emotional health as well as the activity patterns that contribute to physical health.

Modern urban residents can enjoy substantial access to natural areas and amenities, i.e. green infrastructure, within our cities. City and private parks, community gardens, grassy plazas, and rooftop patios on green roofs all provide sources of nature that urban residents can enjoy. Access to these urban oases of nature can have a positive impact on human health in a variety of ways, such as lowering obesity rates by encouraging outdoor play and recreation, speeding the healing process for hospital patients following illness or surgery, and improving the mental and emotional development of children.[59] Interacting with examples of so-called "unthreatening nature" (i.e. trees, potted plants, or landscaped parks, rather than "threatening nature" examples such as dark, secluded woods) in urban settings can contribute to positive emotional outlook, decreased stress levels, less anger and road rage, a higher tolerance for frustration or pain, and increased attention span.[60] The studies described in the following tables offer examples of how green infrastructure in cities improves human health and well-being.

[55] Bruegmann, R. 2006. *Sprawl: A compact history.* Chicago, IL: University of Chicago Press. 301pp.
[56] Lederbogen, F., P. Kirsch, L. Haddad, F. Streit, H. Tost, P Schuch, S. Wust, J.C. Pruessner, M. Rietschel, M. Deuschle, & A. Meyer-Lindenberg. 2011. City living and urban upbringing affect neural social stress processing in humans. *Nature,* 474: 498-501.
[57] As quoted on p. 168 of Tzoulas, K., K. Korpela, S. Venn, V. Yli-Pelkonen, A. Kazmierczak, J. Niemela, & P. James. 2007. Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and Urban Planning,* 81: 167-178.
[58] Tzoulas et al. 2007.
[59] Joye, Y., K. Willems, M.Brengman, & K. Wolf. 2010. The effects of urban retail greenery on consumer experience: Reviewing the evidence from a restorative perspective. *Urban Forestry & Urban Greening,* 9: 57-64; Wolf, K. 2008. City Trees, Nature and Physical Activity: A Research Review. *Arborist News,* 17(1): 22-24; Tzoulas et al. 2007
[60] Joye et al. 2010.

Nature speeds hospital recovery

A seminal study on the effects of nature on human health was published by Roger S. Ulrich in 1984 in the journal *Science*. Ulrich reviewed patient records from a Pennsylvania hospital between 1976-1981 to see whether patients in rooms with a window view of leaf-on deciduous trees recovered any faster following a routine surgery than matched (similar) patients in rooms with a view of a brick wall.[61] He found that patients with windows overlooking trees had shorter hospital stays following surgery and took fewer and weaker doses of painkillers than patients without treed views.[62] Ulrich hypothesized as a result of this study that views of nature were reducing individuals' perception of pain, and thus speeding up the physiological process of healing.

Nature decreases stress

A 1991 study by Ulrich and colleagues further examined the physiological effects of viewing nature.[63] This study measured the changes in blood pressure, heart rate, and muscle tension (among other physiological factors) while people watched first a stressful video followed by a neutral video of either natural (dominance of vegetation and/or water features) or urban (absence of vegetation) scenes.[64] The researchers found that people who watched the nature video second recovered to a normal physiological state (blood pressure, heart rate and muscle tension) following the stress of the first video more quickly than those who watched the urban video.[65] Thus, natural scenes contributed to a restorative experience and stress recovery for individuals.[66]

Nature improves the health of children

Another effect of nature on individual health is the ability of nature to increase attention and focus and decrease attention deficit problems in children. Researchers at the Human-Environment Research Laboratory at the University of Illinois have discovered that children with Attention Deficit Disorder (ADD) exposed to natural settings for play time have less severe ADD symptoms following this exposure than those without a "green" play area.[67] Additionally, in his best-selling book, *Last Child in the Woods*, Richard Louv presents a host of research indicating that nature plays a key role in the mental, emotional and physical development of children.[68]

Nature encourages walking and recreation

Green infrastructure such as street trees can also improve the pedestrian environment and encourage walking for exercise as well as for destination-based travel (such as to and from work or school).[69] Because people perceive distances along 'green' (i.e., heavily vegetated) streets to be shorter than distances along streets lacking vegetation (see also Figure 1), people are more likely to choose walking as a mode of transport if green infrastructure is present.[70] Additionally, study in Western Australia revealed that individuals with very good access to large, attractive, public greenspaces were 50% more likely to engage in walking as a physical activity than those without access.[71]

[61] Ulrich, R.S. 1984. View through a window may influence recovery from surgery. *Science*, 224: 420-421.
[62] Ulrich 1984.
[63] Ulrich, R.S., R.F. Simons, B.D. Losito, E.Fiorito, M.A. Miles, & M. Zelson. 1991. Stress recovery during exposure to natural and urban environments. *Journal of Environmental Physiology*, 11: 201-230.
[64] Ulrich et al. 1991.
[65] Ibid.
[66] Ulrich et al. 1991.
[67] Taylor, A.F., F.E. Kuo, & S.C. Sullivan. 2001. Coping with ADD: The surprising connection the green play settings. *Environment and Behavior*, 33(1): 54-77.
[68] Louv, R. 2005. Last Child in the Woods: Saving our Children from Nature-Deficit Disorder. Chapel Hill, NC: Algonquin Books. 390pp.
[69] Jackson, L.E. 2003. The relationship of urban design to human health and condition. *Landscape and Urban Planning*, 64: 191-200; Wolf 2008.
[70] Wolf 2008.
[71] Giles-Corti, B., M.H. Broomhall, M. Knuiman, C. Collins, K. Douglas, K. Ng, A. Lange, & R.J. Donovan. 2005. Increasing walking: How important is distance to, attractiveness, and size of public open space? *American Journal of Preventative Medicine*, 28(2S2): 169-176.

There are several hypothesized mechanisms for the influence of urban greenspace and vegetation on human health. The presence of urban vegetation improves both the physical comfort (by reducing the urban heat island effect – see the BEQI Green Infrastructure subsection on UHI Mitigation) and the aesthetic appeal (by increasing the visual interest of a streetscape – see Figure 1) of a city and its pedestrian environment, which makes people more likely to walk and participate in outdoor recreation.[72] Additionally, viewing nature can be a restorative experience that lowers blood pressure and muscle tension, relaxing people both physically and mentally. This effect has been observed even for individuals viewing video footage of nature.[73]

(a) **(b)**

Figure 1. Individuals are much more likely to walk or recreate in areas with trees (a) than in those without (b). (*Image source:* Wolf, K.L. 2009. Trees Mean Business: City trees and the Retail Streetscape. *Main Street News,* 263: 1-9.)

Although many researchers are careful to point out that the evidence quantifying the association of nature and greenspace with increased health benefits is only preliminary, green infrastructure is clearly a contributing factor to human health in cities. Continued research is needed to more clearly define the specific health impacts afforded by various types of green infrastructure. (For more research on the impacts of green infrastructure on human health, see the website of the Landscape and Human Health Laboratory at the University of Illinois, Urbana-Champaign, and the Green Cities: Good Health website, sponsored by the University of Washington and the US Forest Service Urban & Community Forestry Program).

[72] Tzoulas et al. 2007.
[73] Tzoulas et al. 2007; Ulrich et al. 1991.

Human health and well-being and green infrastructure in Bloomington

Green infrastructure in Bloomington contributes to the health and well-being of people our community. In order to assess the potential contribution of green infrastructure to aid human health, the City of Bloomington has chosen the following indicators. (For a complete list of all indicators for all categories, click here):

- **Indicator #2a: Number of Certified Backyard Wildlife Habitats in Bloomington.** Backyard Wildlife Habitats not only provide opportunities for restorative nature viewing, but also offer a chance for individuals to increase their 'ecological literacy' and appreciation of nature.

- **Indicator #3a: Number (and area) of community garden plots.** The greater the number and size of community garden plots available, the more opportunities people in the community have to engage in gardening activities.

- **Indicator #3b: Number of community garden plot gardeners.** People who participate in community gardening not only build social capital, but they also decrease their risk of negative health effects resulting from isolation.

- **Indicator #3c: Number of Certified Master Gardeners in Bloomington:** Similar to the number of community plot gardeners, the number of Certified Master Gardeners is an indication not only of social capital related to gardening, but also of the amount of dedicated gardening occurring, thereby indirectly impacting human health.

- **Indicator #3e: Number of volunteers (to-date) at the Bloomington Community Orchard.** The number of volunteers at the Bloomington Community Orchard is an indication not only of social capital, but also of the amount of garden related activities occurring, thereby indirectly supportive of human health and well-being.

- **Indicator #4c: Number (and area) of "conservancy easements," as defined by the City Unified Development Ordinance (UDO) and dedicated by developers.** The amount of developer-created "conservancy easements" in Bloomington is a proxy for the availability of quiet, restorative experiences in nature as well as natural window views.

- **Indicator #4d: Number of developments with green roofs.** Green roofs can be another source of greenery for natural views from windows. Patios on green roofs offer further opportunity for contemplative experiences in nature.

- **Indicator #5a: Number (and area) of public parks in Bloomington.** Public parks offer a plethora of opportunities for natural views, recreational activity, as well as quiet contemplation in nature, all experiences that contribute to improved human health.

- **Indicator #6b: Percent (and area) of total greenspace in Bloomington.** The more greenspace in Bloomington, the more opportunities residents have to view and recreate in nature, which improves individual health.

- **Indicator #6c: Percent (and area) of greenspace in a ½ mile buffer of medical facilities.** Because nature and natural views have proven explicitly beneficial to speeding recovery of hospital patients, greenspace near hospitals is particularly important to improving human health.

- **Indicator #6d: Percent (and area) of greenspace in a ½ mile buffer of K-12 schools.** Because greenspace and nature has also proven important to children's attention and focus as well as to their overall mental development, greenspace within schools is critical to ensuring the mental health of Bloomington's children. Additionally, greenspace near schools has also been shown to increase the willingness of students (and of parents to allow their children) to walk to school, thereby increasing opportunities for physical activity.

How does Bloomington measure up on these indicators?

The following table tells us how Bloomington stacks up on each of the above indicators related to increasing human health and well-being using green infrastructure. The complete list of green infrastructure indicators can be seen here.

Green Infrastructure Indicator	Value *	Last update
#2a: Number of Certified Backyard Wildlife Habitats in Bloomington.	327 [d]	2012
#3a: Number (and area) of community garden plots	221 (11.469 acres) [h]	2012
#3b: Number of community garden plot gardeners	442 [h]	2012
#3c: Number of Certified Master Gardeners in Bloomington	160 [i]	2012
#3e: Number of volunteers (to-date) at the Bloomington Community Orchard	584 [j]	2012
#4c: Number (and area) of "conservancy easements," as defined by the City Unified Development Ordinance (UDO) and dedicated by developers.	10 (79.107 acres) [m]	2008
#4d: Number of developments with green roofs.	3 [l]	2011
#5a: Number (and area) of public parks in Bloomington.	26 (214.02 acres) [o]	2012
#6b: Percent (and area) of total greenspace in Bloomington.	38.5% (6,429.3 acres) [r]	2007
#6c: Percent (and area) of greenspace in a ½-mile buffer of medical facilities.	34.14% (979.22 acres) [s]	2007
#6d: Percent (and area) of greenspace in a ½-mile buffer of K-12 schools.	25.22% (1,769.56 acres) [t]	2007

[*] *Footnotes on values in table indicate the source of the information for the indicator:*

[d] Roxanne Paul, National Wildlife Federation, personal communication, 3 July 2012.

[h] Robin Hobson, Bloomington Parks & Recreation Department, personal communication, 8 June 2012. Note: Willie Streeter has 180 rental plots and 1.26 acres, Butler Park has 38 rental plots and .39 acres, Cresmont Park has 0 rental plots and .26 acres, Banneker Green Thumbs Garden has 0 rental plots and .041 acres, Harmony School Garden has 0 rental plots and .018 acres, Hilltop Garden and Nature Center has 0 rental plots and 5.0 acres, and the Permaculture Growers Co-Op has 3 rental plots and 4.5 acres. It is assumed that there are 2 gardeners per rental plot available.

[i] Amy Thompson, Monroe County Cooperative Extension Service, personal communication, 18 June 2012.

[j] Amy Countryman, Bloomington Community Orchard, personal communication, 1 July 2012. Amanda Werhane, Bloomington Community Orchard, personal communication, 30 June 2012. Broken down by year: 2010: 195 volunteers; 2011: 374 volunteers; 2012(January-June): 96 volunteers.

[l] The City of Bloomington Planning Department. Environmental Agreements of Developments Database.

[m] Linda Thompson, City of Bloomington Planning Department, "Conservancy Easements Database", 24 August 2012. Addresses (area): 2401 W. Tapp Road (59 acres); 3600 N. Prow Road (acres N/A); 3201 S. Wickens Street (acres N/A); 2310 W. 3rd Street (acres N/A); 1300 W. Countryside Lane (1.057 acres); 1201 S. Smith Road (acres N/A); 751 E. Tamarack Trail (1.78 acres); 2107 W. 3rd Street (17.27 acres); 3111 S. Walnut Street Pike (acres N/A); 2410 E. Moores Pike (acres N/A).

[o] Acreage Inventory data obtained from Dave Williams, City of Bloomington Parks & Recreation Department, 08 June 2012. Note: only based on "developed" acreage in Broadview Park, Bryan Park, Building & Trades Park, Upper and Lower Cascades Park, Crestmont Park, Ferguson Park, Griffy Lake Nature Preserve, Highland Village Park, Leonard Springs Nature Park, Maple Heights Park, Miller-Showers Park, Olcott Park, Park Ridge Park, Park Ridge East Park, Peoples Park, RCA Community Park, Reverend Butler Park, Schmalz Farm Park, Seminary Park, Sherwood Oaks Park, Southeast Park, and Third Street Park.

[r] City of Bloomington Environmental Commission & C. Winkle. 2007. Greenspace trends in Bloomington, Indiana 1993-2007. City of Bloomington, Indiana. 11pp. Online available at https://bloomington.in.gov/media/media/application/pdf/2738.pdf. Last accessed 30 June 2011.

[s] Chuck Winkle, City of Bloomington GIS, 24 August 2012. Note: Includes hospitals and other facilities, such as nursing homes, that provide overnight care for patients that will eventually return home after short-term or medium-term stays. Facilities: Jill's House at 751 E. Tamarack Trail, Bloomington, Indiana 47408; Golden Living Center at 155 E. Burks Drive, Bloomington, IN 47401; IU Health Bloomington Hospital at 601 W. 2nd Street, Bloomington, IN 47403; Meadowood Retirement Community at 2455 N. Tamarack Trail, Bloomington, IN 47408; Monroe House at 2770 S. Adams Street, Bloomington, IN 47403; Bloomington Nursing and Rehabilitation Center at 120 E. Miller Drive, Bloomington, IN 47401.

[t] Chuck Winkle, City of Bloomington GIS, 24 August 2012. Note: Includes both Public and Private schools.

ECOSYSTEM SERVICE #6: WILDLIFE HABITAT AND BIODIVERSITY

In addition to the numerous benefits to humans described above, green infrastructure also provides habitat to wildlife and preserves biodiversity in cities. Wildlife habitat is any (usually vegetated) area that provides food, shelter, and an overall suitable home for animals, including birds, small mammals, frogs, and even, in streams or ponds, fish. The different species of animals and plants living in a habitat make up an ecological community, meaning that these species live in the same geographical area and interact with one another through competition for resources (food, shelter, water, etc.) as well as through predation (where one animal eats another). An ecological community includes many different populations, or groups, of different individuals of the same species living together, and the number of different species populations combined with the genetic differences between individuals within the same population and species is called biodiversity.

The fact that rural and forested areas contain spaces of wildlife habitat may be obvious, but wildlife habitat also exists in urban areas, if often on a smaller scale. Instead of undisturbed habitats that stretch for miles and miles, such as the Hoosier National Forest, urban areas typically contain smaller habitat patches, such as Dunn Woods on the Indiana University Campus, and even the yard or garden around your home.

Healthy wildlife habitat and adequate biodiversity in urban areas can serve two main functions: first, patches of mature vegetation in urban areas help compensate to the habitat loss that urbanization implies,[74] and can provide habitat for wildlife moving through urban areas, such as populations of migrating birds.[75] Second, a diverse habitat within urban areas helps promote other supporting ecosystem services within cities, including housing populations of pollinators for urban gardens, fruit trees, or and nearby agricultural areas, as well as maintaining healthy soil. Healthy populations of vegetation – such as trees within the urban forest – provide habitat for urban wildlife and are a source of biodiversity in their own right.

Backyard Wildlife Habitats

Backyard Wildlife Habitats are a form of landscaping involving the creation of naturalized landscapes that include native plants and that provide food, shelter and habitat to animals. By fostering native biodiversity, Backyard Wildlife Habitats help restore ecosystems and their services to the landscape. For example, naturalized landscapes help to stabilize soils. This is especially needed on steep slopes, stream banks, or areas near water bodies. Roots of native plants are better adapted to local soils, and often grow dense and deep root systems compared to lawn turf. These larger root systems mean that native plants are especially useful at holding the soil in place and minimizing erosion. The well-developed root systems of naturalized landscapes can also improve water quality since they can intercept runoff and pollutants before entering water sources. Because they are biologically suited to local growing conditions, native plants are hardy, and do not require costly, toxic chemical applications, or sometimes even watering, to survive.[76]

Additionally, naturalized landscapes reduce the need for fossil-fuel powered lawn equipment. Gas-powered mowers and other equipment harm the environment by emitting greenhouse gases and noxious, smog-forming gases and particulates, thus contributing to global warming and air pollution. Furthermore, the EPA estimates that the small amounts of gasoline spilled when refueling mowers cumulatively adds

[74] McKinney, M.L. 2002. Urbanization, biodiversity, and conservation. *BioScience*, 52(10): 883-840.
[75] James, P., D. Norman, & J.J. Clarke. 2010. Avian population dynamics and human induced change in an urban environment. Urban Ecosystems, 9 July 2010. 17pp.
[76] U.S. Environmental Protection Agency. 2008b. "Chapter 2: What are the Benefits of Natural Landscaping?" *Green Landscaping: Greenacres, A Source Book on Natural Landscaping for Public Officials.* Online available at http://epa.gov/greenacres/toolkit/chap2.html. Last accessed 13 Aug 2011.

up to 17 million gallons of gas each summer.[77] Naturalized landscapes can greatly reduce these risks to human health and the quality of local air, soil, and water. (To learn more about the benefits of naturalized landscaping, visit EPA's Beneficial Landscaping page. To learn more about how to landscape with native plants, visit the Environmental Commission's Natural Landscaping webpage.)

The National Wildlife Federation's (NWF) Backyard Wildlife Habitat Program was established 1973 and is dedicated to promoting the creation or restoration of natural landscapes in human surroundings.[78] Backyard habitats provide food, water, shelter, and space for insects, plants, and animals, and can range in size from a single city balcony to an entire community. Through the efforts of the Center for Sustainable Living, Bloomington was registered as a Community Wildlife Habitat in January 2002. Numerous homes, schools, businesses, and churches in Bloomington have NWF-certified Backyard Wildlife Habitats. In total, over 100 sites have been certified.[79] This amount is well above other comparable Midwestern cities (Figure 1). As naturalized lawns become more popular within the city, many additional areas will qualify as Backyard Wildlife Habitats.

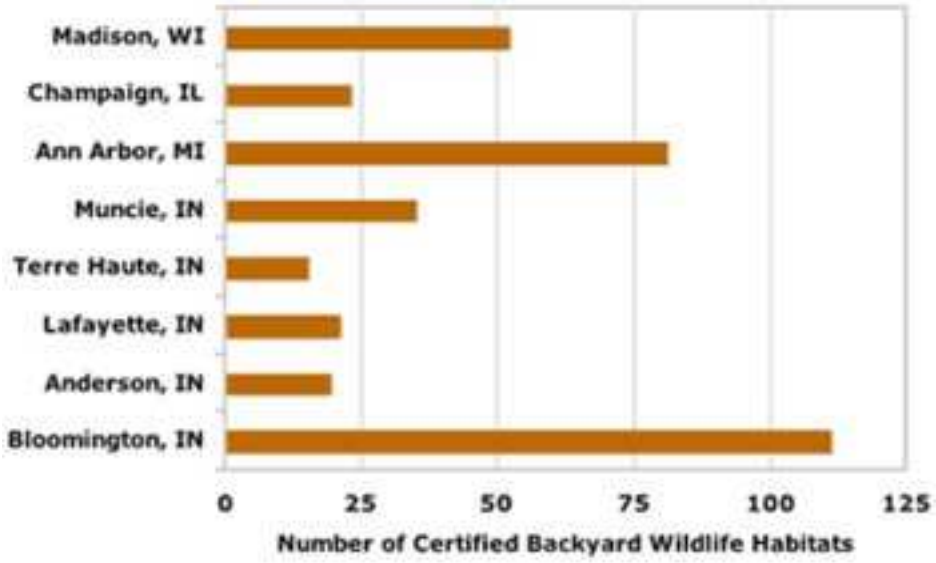

Figure 1. Certified Backyard Wildlife Habitats in several Midwestern cities in 2006. (*Source:* Roxanne Paul, National Wildlife Federation, personal communication, 23 Mar 2006.)

It is important to note that some people consider wildlife in urban areas, such as deer, to be undesirable pests and for this reason do not want to increase the amount of wildlife habitat in cities. However, deer problems in urban areas often result not from incorporating more green infrastructure within the existing boundaries of cities, but instead from the encroachment of development at the edges of cities into relatively undisturbed wildlife habitat, such as forests or grasslands.[80] Additionally, there is often confusion over what qualifies as natural landscaping. Bloomington has a weed ordinance to prevent land

[77] U.S. Environmental Protection Agency 2008b.
[78] National Wildlife Federation. 2011. "History of the Backyard Wildlife Habitat Program." *Garden for Wildlife: Making Wildlife Habitat at Home.* Online available at: http://www.nwf.org/Get-Outside/Outdoor-Activities/Garden-for-Wildlife/Gardening-Tips/History-of-the-Backyard-Wildlife-Habitat-Program.aspx?CFID=21426989&CFTOKEN=d843d6ceb177a33f-C3C309B7-5056-A84B-C37E4D3AB5D61D41. Last accessed 13 Aug 2011.
[79] Roxanne Paul, National Wildlife Federation, personal communication, 23 Mar 2006.
[80] Jackson, L.E. 2003. The relationship of urban design to human health and condition. *Landscape and Urban Planning*, 64: 191-200.

within city limits from becoming overrun with weeds or noxious plants above eight inches tall.[81] This ordinance is in place to protect public health and prevent unsightly landscapes. However, natural landscaping, which involves clear intentions and goals, does not pose the same threat that the weed ordinance guards against. For example, unwanted pests attracted to unkempt yards are not drawn to areas with well designed natural landscapes. Due to the environmental and economic benefits of natural landscaping, many communities - including Bloomington - are attempting to modify weed ordinances to accommodate naturalized yards.

Exotic or Invasive Species

Increased global trade and travel have led to the introduction of invasive species into new areas, a trend that poses a substantial threat to urban wildlife habitat as well as to biodiversity. The Environmental Protection Agency defines invasive species as non-native (or exotic) plants, animals, or microbes that proliferate and spread in ecosystems, causing economic, human health, or environmental damage.[82] Invasive species often lack natural predators, or other natural control agents, and it is therefore very difficult to control their spread once a population is established. Invasive species aggressively compete against and displace native species, inhibiting ecosystem functioning. Hydrology, nutrient cycling, and food webs can all be altered due to non-native species invasions.[83]

Invasive plant species are problematic across Indiana, and Bloomington is no exception. A well-known example of the local problem is at Griffy Lake, where invasive *Brazilian elodea* had become established and was until recently threatening native aquatic vegetation. In Bloomington, as in many communities, proposed plans to manage invasive species have led to heated debates over issues such as chemical versus mechanical means of control. Another local area where invasive species have become established is Cedar Bluffs Nature Preserve, located just southwest of Bloomington. Cedar Bluffs has been invaded by species such as winter creeper, Japanese knotweed, privet, and Japanese hops. Each of these plants likely spread to the preserve from local landscape plantings on nearby private land. (For a list of common invasive species in Bloomington, visit the Environmental Commission Invasive Species webpage.)

Urban areas are especially vulnerable to invasive species because they experience a high throughput of goods and people, giving many chances for non-native species to be introduced. Additionally, the disturbed soils and ecosystems in cities have been demonstrated to be more vulnerable to invasive species than undisturbed ecosystems.[84] Thus, preservation of healthy green infrastructure in cities depends also on the successful management of invasive species.

In order to maintain the ecosystem service of wildlife habitat provision afforded by green infrastructure, efforts should be made to remove or control invasive plants and animals. The City of Bloomington is committed to controlling present and future invasions of invasive plant species. To promote healthy and functioning ecosystems, Bloomington and its residents must attempt to reduce or eliminate invasive species in the community. Only through education and hands-on management can the damage to natural landscapes in Bloomington be minimized.

[81] U.S. Environmental Protection Agency 2008b.
[82] U.S. Environmental Protection Agency. 2008c. "Invasive Non-Native Species." *Watershed Academy Web*. Online available at http://www.epa.gov/owow/watershed/wacademy/acad2000/invasive.html. Last accessed 13 Aug 2011.
[83] Mack, R.N., D. Simberloff, W.M. Lonsdale, H. Evans, M. Clout, & F.A. Bazzaz. 2000. Biotic invasions: causes, epidemiology, global consequences, and control. *Ecological Applications*, 10(3): 689-710.
[84] Ibid.

Wildlife habitat, biodiversity and green infrastructure in Bloomington

Many of the features of Bloomington's green infrastructure provide habitat for wildlife and preserve local biodiversity. The City of Bloomington has chosen the following indicators to show the effect of green infrastructure on wildlife habitat and biodiversity. (For a complete list of all indicators for all categories, click here):

- **Indicator #1b: Percent of street trees that are large/mature (>18" in diameter).** Large, mature trees provide habitats for nesting birds and small mammals. Masting trees also provide a food source for wildlife, including birds, as well as a seed source for urban vegetation in vacant lots and remnant habitats.
- **Indicator #1c: Percent of street trees that are young (<6" diameter).** Young street trees ensure that biodiversity will persist into the future. An adequate proportion of young plants also add a generational element to the concept of diversity.
- **Indicator #1d: Percent of street trees of top most abundant species, genus, and family.** A population of street trees (as a sub-sample of the entire urban forest) where no more than 10% of the trees are a single species, no more than 20% a single genus, and no more than 30% a single family helps ensure diversity in the face of outbreaks of pest or disease, as well as provides habitat for a greater diversity of wildlife.
- **Indicator # 1e: Alpha diversity (or total number of species) of street trees.** A large number of species of street trees also helps guard the urban forest against pests and disease, but also helps provide a seed source for outlying areas (wind-pollinated trees)
- **Indicator #2a: Number of Certified Backyard Wildlife Habitats in Bloomington.** Backyard Wildlife Habitats are designed to attract and sustain wildlife and native plant species and contribute to biodiversity.
- **Indicator #2b: Number of local groups working (since 2010) to control invasive species.** Because invasive species can threaten the quality and quantity of wildlife habitat, efforts to control or eradicate these threats can be important.
- **Indicator #4b: Percent of new developments (since 2001) with native species plantings.** Planting native species in the landscaping of new developments (instead of exotics) helps provide habitat for native wildlife, particularly birds and butterflies.
- **Indicator #4c: Number (and area) of "conservancy easements," as defined by the City Unified Development Ordinance (UDO) and dedicated by developers.** Conservancy easements help preserve areas of natural or semi-natural remnant habitat within the city, creating patches of relatively undisturbed vegetation through which animals (and plant seed) populations can travel when passing through an urban area (e.g., stopover sites for migrating birds).
- **Indicator #4d: Number of developments with green roofs.** Green roofs provide habitat for insects and can increase the insect diversity of an urban area relative to conventional roofs. Green roofs can also provide butterfly and bird habitat, if designed for such purposes.
- **#6a: Number (and area) of conservation easements owned by nonprofits or government agencies.** Legal conservation easements provide some of the same benefits as City-defined "conservancy easements," (except these easements may provide higher habitat quality as a result of greater legal restrictions on activities in the easements and organizational standards for easement acquisition).
- **Indicator #6b: Percent (and area) of total greenspace in Bloomington.** Greenspace, although it can vary substantially in quality of habitat, provides at least minimal habitat for urban wildlife, particularly, small mammals, birds and insects.

How does Bloomington measure up on these indicators?

The following table tells us how Bloomington stacks up on each of the above indicators related to promoting wildlife habitat and biodiversity with green infrastructure. The complete list of green infrastructure indicators can be seen here.

Green Infrastructure Indicator	Value *	Last update
#1b: Percent of street trees that are large/mature (>18" in diameter).	17% [a]	2007
#1c: Percent of street trees that are young (<6" in diameter).	26.7% [a]	2007
#1d: Percent of street trees of top most abundant species, genus, and family.	16.9% red maple, 31.1% *Acer* genus [a]	2007
#1e: Alpha diversity (or total number of species) of street trees	100 [a]	2007
#2a: Number of certified Backyard Wildlife Habitats in Bloomington	327 [d]	2006
#2b: Number of local groups working (since 2010) to control invasive species.	5 [e]	2012
#4b: Number (and percent) of new developments (since 2001) with native species plantings.	20 (13%) [l]	2011
#4c: Number (and area) of "conservancy easements," as defined by the City Unified Development Ordinance **(**UDO) and dedicated by developers.	10 (79.107 acres) [m]	
#4d: Number of developments with green roofs.	3 [l]	2011
#6a: Number (and area) of conservation easements owned by nonprofits or government agencies.	4 (266.2 acres) [q]	2012
#6b: Percent (and area) of total greenspace in Bloomington.	(38.5%) 6,429.3 acres [r]	2007

* *Footnotes on values in table indicate the source of the information for the indicator:*

[a] Fischer, B.C., M. Steinhoff, S. Mincey, & L. Dye. 2007. The 2007 Bloomington Street Tree Report: An Analysis of Demographics and Ecosystem Services. Bloomington Urban Forestry Report 01-07. Available at http://bloomington.in.gov/media/media/application/pdf/2337.pdf.

[d] Roxanne Paul, National Wildlife Federation, personal communication, 3 July 2012.

[e] Data collection range limited to a start date of 2010. Agencies mentioned for this indicator conduct periodic invasives removal efforts. Sources: Ellen Jacquart, The Nature Conservancy and Monroe County – Identify and Reduce Invasive Species group, personal communication, 14 June 2012. Richard Ciasto, Director of Operations, Eco Logic LLC, personal communication, 5 July 2012 (removal efforts conducted at Cascades Park and at Latimer Woods). Joel Grant, City of Bloomington Parks and Recreation, personal communication, 3 July 2012. John Lawrence, Assistant Director, Sycamore Land Trust, personal communication, 13 July 2012. Indiana University, Mia Williams, University Landscape Architect - Indiana University, personal communication 22 October 2012. (Williams notes that many groups across campus conduct various removal efforts. Ongoing initiatives include the IU Campus Division's work removing *Euonymus*, honeysuckle, tree-of-heaven, and the Dunn's Woods Restoration Project. Volunteer days arranged by these two groups regularly involve students, faculty, staff and other community members).

[l] The City of Bloomington Planning Department. Environmental Agreements of Developments Database.

[m] Linda Thompson, City of Bloomington Planning Department, "Conservancy Easements Database", 24 August 2012. Addresses (area): 2401 W. Tapp Road (59 acres); 3600 N. Prow Road (acres N/A); 3201 S. Wickens Street (acres N/A); 2310 W. 3rd Street (acres N/A); 1300 W. Countryside Lane (1.057 acres); 1201 S. Smith Road (acres N/A); 751 E. Tamarack Trail (1.78 acres); 2107 W. 3rd Street (17.27 acres); 3111 S. Walnut Street Pike (acres N/A 2410 E. Moores Pike (acres N/A).

[q] 1. Sycamore Land Trust holds two conservation easements within Bloomington city limits. One is 16 acres on Lot 1 and Lot 2 of the Sakes Tarzian Subdivision. The county assessor's property cards list the addresses for these lots as 1113 E. Hillside Drive and 1020 S. Highland Avenue. The easement was recorded as instrument #2002007421 on 4/1/2002 and rerecorded as instrument #2012003734 on 3/9/2012. The other easement is about 0.2 acres, covering the south half of Lots 9 and 10 of the Allendale Addition. The property address is 717 S. Henderson Street. The easement was recorded as instrument #2002030757 on 12/19/2002. (John Lawrence, Assistant Director of Sycamore Land Trust, personal communication, 20 June 2012). 2. Bloomington Parks and Recreation holds two parcels at Griffy Lake that have official conservation easements: the original state-dedicated Griffy Woods Nature Preserve, which included 240 acres, and the 10-acre Schneider property, which was added to the state-dedicated preserve. (Steve Cotter, Natural Resources Manager, Bloomington Parks and Recreation).

[r] City of Bloomington Environmental Commission & C. Winkle. 2007. Greenspace trends in Bloomington, Indiana 1993-2007. City of Bloomington, Indiana. 11pp. Online available at https://bloomington.in.gov/media/media/application/pdf/2738.pdf. Last accessed 30 June 2011.

Threats to green infrastructure and urban ecosystem services

For the first time in history, the number of people living in cities outnumbers those living in rural areas. This is true globally as well as within the United States.[85] This means that urban ecosystems as providers of ecosystem services are more important than ever. Monitoring and tracking the features of green infrastructure that contribute to urban ecosystem services is important to maintaining these benefits and ensuring a high quality urban environment for city dwellers, just as maintaining healthy ecosystems in rural areas is key to sustaining the ecosystem services provided by those areas.[86]

Globally, the largest threats to ecosystem services include land use changes leading to habitat loss, exotic species invasions, loss of biodiversity, pollution, and climate change. In urban, suburban, and urbanizing areas, the expansion of cities in both geographic extent and population size is resulting in the conversion of rural to urban land at an astonishing rate. Between 1982 and 1997, the U.S. experienced a 47% increase in land development while the U.S. population increased only by 17%.[87] Over the past two decades, the rate of land development has been fully twice that of population growth.[88]

Americans clearly recognize the problems rapid development presents. One pool in 2000 ranked urban sprawl at the same level as crime and violence as a top problem facing communities.[89] As rural land such as forest, pasture, timber fields, and agricultural land are replaced with residential suburbs, business parks, and industrial areas, there are various environmental consequences. Examples include increased flooding risks due to increased urban runoff and decreased stormwater infiltration, higher urban temperatures caused by increased heat absorption and decreased vegetative evapotranspiration, and decreased biodiversity resulting from the loss of wildlife habitat.[90] Incorporating sufficient green infrastructure within cities can mitigate these negative effects of urbanization.

To combat the loss of land to development, municipal and non-governmental groups in the City of Bloomington and across the country are seeking to acquire and preserve local greenspace. Greenspace is operationally defined as open land in a natural or restored state with vegetation and permeable ground. By hosting local ecosystems, greenspace can maintain and promote the range of ecosystem services discussed above, from natural pollinators to flood mitigation and climate modulation. However, despite the City's efforts, 24.4% of the city's greenspace was lost between 1993 and 2007 (Figure 1).[91] (For more information on the recent history of greenspace in Bloomington, see the three greenspace reports on the Environmental Commission website.)

[85] United Nations Department of Economic and Social Affairs, Population Division. 2010. *World Urbanization Prospects, The 2009 Revision: Highlights.* New York, NY: United Nations. 56pp. [Online] Available at http://esa.un.org/unpd/wup/Documents/WUP2009_Highlights_Final.pdf. Last accessed 14 Jul 2011.
[86] Turner, R.K. & G.C. Daily. 2008. The ecosystem services framework and natural capital conservation. *Environ Resource Econ*omics, 39:25-35.
[87] Williamson, K.S. 2003. Growing with green infrastructure. Heritage Conservancy. 16pp. [Online] Available at http://www.dcnr.state.pa.us/brc/publications/Pubs/green_infra.pdf. Last accessed 2 Jun 2011.
[88] U.S. Environmental Protection Agency. 2007. Reducing stormwater costs through Low Impact Development (LID) strategies and practices. EPA 841-F-07-006. Washington, D.C.: United States Environmental Protection Agency, Nonpoint Source Control Branch. [Online] Available at http://water.epa.gov/polwaste/green/upload/2008_01_02_NPS_lid_costs07uments_reducingstormwatercosts-2.pdf. Last accessed 13 Jul 2011.
[89] http://www.greeninfrastructure.net/
[90] Alberti, M. 2008. *Advances in Urban Ecology: Integrating Humans and Ecological Processes in Urban Ecosystems.* New York, NY: Springer. 366 pp.
[91] City of Bloomington Environmental Commission & C. Winkle. 2007. Greenspace trends in Bloomington, Indiana 1993-2007. City of Bloomington, Indiana. 11pp. [Online] Available at https://bloomington.in.gov/media/media/application/pdf/2738.pdf. Last accessed 30 June 2011.

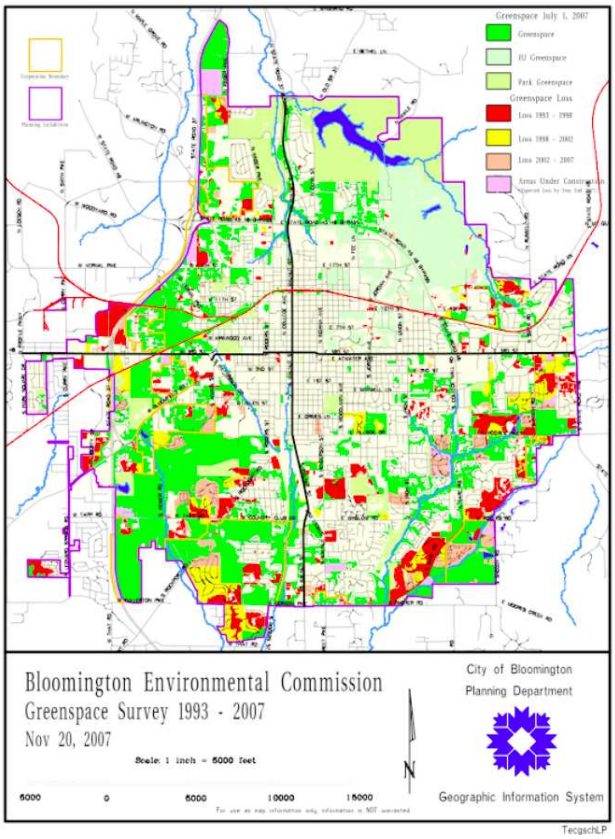

Figure 1. Greenspace loss from 1993 to 2007 for the City of Bloomington. [*Source:* City of Bloomington Environmental Commission & C. Winkle. 2007. Greenspace trends in Bloomington, Indiana 1993-2007. City of Bloomington, Indiana. 11pp. [Online] Available at https://bloomington.in.gov/media/media/application/pdf/2738.pdf. Last accessed 30 June 2011. See this source for a full size map.]

Minimizing these threats to green infrastructure is crucial for the provision the of ecosystem services in urban areas. In order to sustain stormwater management services, increase business and home values, mitigate urban heat island effects, maintain urban agriculture, improve human health and well being, and provide wildlife habitat and preserve biodiversity in Bloomington, all types of green infrastructure are necessary. From street trees and Backyard Wildlife Habitats, to green roofs and biofiltration ponds, increasing the amount of green infrastructure in the City of Bloomington will help establish and preserve a high quality urban environment capable of supplying ecosystem services.

ALL GREEN INFRASTRUCTURE INDICATORS

There are several main features of green infrastructure that contribute to provision of the ecosystem services discussed on this website. This table organizes all of the Green Infrastructure Indicators by the type of environmental feature they represent.

Green Infrastructure Feature and Indicator	Value *	Last update
FEATURE #1: STREET TREES		
#1a: Percent of street tree spaces filled.	75% [a]	2007
#1b: Percent of street trees that are large/mature (>18" in diameter).	17% [a]	2007
#1c: Percent of street trees that are young (<6" in diameter).	26.7% [a]	2007
#1d: Percent of street trees of top most abundant species, genus, and family.	16.9% *red maple sp.* 31.2% *Acer genus* [a]	2007
#1e: Alpha diversity (or total number of species) of street trees.	100 [a]	2007
#1f: Ratio of the number of trees planted to number removed per year.	388:125 [b]	2007
#1g: Tree City USA status and Tree City Growth Award secured yearly.	YES and NO [b]	2010
FEATURE #2: NATURAL LANDSCAPING		
#2a: Number of Certified Backyard Wildlife Habitats in Bloomington.	327 [c]	2012
#2b: Number of local groups working (since 2010) to control invasive species.	5 [d]	2012
FEATURE #3: URBAN AGRICULTURE AND GARDENING		
#3a: Number (and area) of community garden plots	221 (11.469 acres) [g]	2012
#3b: Number of community garden plot gardeners	442 [g]	2012
#3c: Number of Certified Master Gardeners in Bloomington	160 [h]	2012
#3d: Number of trees in the Bloomington Community Orchard	75 [i]	2012
#3e: Number of volunteers (to-date) at the Bloomington Community Orchard	584 [i]	2012
FEATURE #4: GREEN DEVELOPMENT PRACTICES		
#4a: Number (and percent) of new developments (since 2001) using methods of biofiltration (i.e. bioswale, rain garden, detention pond native plants).	18 (11%) [j]	2011
#4b: Number (and percent) of new developments (since 2001) with native	20 (13%) [j]	2011

species plantings.		
#4c: Number (and area) of "conservancy easements," as defined by the City Unified Development Ordinance (UDO) and dedicated by developers.	10 (79.107 acres) [k]	2008
#4d: Number of developments with green roofs.	3 [j]	2011
FEATURE #5: PUBLIC PARKS AND FACILITIES		
#5a: Number (and area) of public parks in Bloomington.	26 (214.02 acres) [l]	2012
#5b: Number of public facilities using stormwater biofiltration.	6 [m]	2012
FEATURE #6: OTHER URBAN GREENSPACE		
#6a: Number (and area) of conservation easements owned by nonprofits or government agencies.	4 (266.2 acres) [n]	2012
#6b: Percent (and area) of total greenspace in Bloomington.	38.5% (6,429.3 acres) [o]	2007
#6c: Percent (and area) of greenspace in a ½-mile buffer of medical facilities.	34.14% (979.22 acres) [p]	2007
#6d: Percent (and area) of greenspace in a ½-mile buffer of K-12 schools.	25.22% (1,769.56 acres) [q]	2007

[*] *Footnotes on values in table indicate the source of the information for the indicator:*

[a] Fischer, B.C., M. Steinhoff, S. Mincey, & L. Dye. 2007. The 2007 Bloomington Street Tree Report: An Analysis of Demographics and Ecosystem Services. Bloomington Urban Forestry Report 01-07. Available at http://bloomington.in.gov/media/media/application/pdf/2337.pdf.

[b] Tree City USA data obtained from P. Louks, Community & Urban Forestry Coordinator, Indiana Department of Natural Resources, personal communication, 12 February 2010.

[c] Roxanne Paul, National Wildlife Federation, personal communication, 3 July 2012.

[d] Data collection range limited to a start date of 2010. Agencies mentioned for this indicator conduct periodic invasives removal efforts. Sources: Ellen Jacquart, The Nature Conservancy and Monroe County – Identify and Reduce Invasive Species group, personal communication, 14 June 2012. Richard Ciasto, Director of Operations, Eco Logic LLC, personal communication, 5 July 2012 (removal efforts conducted at Cascades Park and at Latimer Woods). Joel Grant, City of Bloomington Parks and Recreation, personal communication, 3 July 2012. John Lawrence, Assistant Director, Sycamore Land Trust, personal communication, 13 July 2012. Indiana University, Mia Williams, University Landscape Architect – Indiana University, personal communication 22 October 2012. (Williams notes that many groups across campus conduct various removal efforts. Ongoing initiatives include the IU Campus Division's work removing *Euonymus*, honeysuckle, tree-of-heaven, and the Dunn's Woods Restoration Project. Volunteer days arranged by these two groups regularly involve students, faculty, staff and other community members).

[g] Robin Hobson, Bloomington Parks & Recreation Department, personal communication, 8 June 2012. Willie Streeter has 180 rental plots and 1.26 acres, Butler Park has 38 rental plots and .39 acres, Cresmont Park has 0 rental plots and .26 acres, Banneker Green Thumbs Garden has 0 rental plots and .041 acres, Harmony School Garden has 0 rental plots and .018 acres, Hilltop Garden and Nature Center has 0 rental plots and 5.0 acres, and the Permaculture Growers Co-Op has 3 rental plots and 4.5 acres. They assume that there are 2 gardeners per rental plot available.

[h] Amy Thompson, Monroe County Cooperative Extension Service, personal communication, 18 June 2012.

[i] Amy Countryman, Bloomington Community Orchard, personal communication, 1 July 2012. Amanda Werhane, Bloomington Community Orchard, personal communication, 30 June 2012. Amy Allen, personal communication 28 September 2012. Volunteer numbers broken down by year: 2010: 195 volunteers; 2011: 374 volunteers; 2012 (January-June): 96 volunteers.

[j] The City of Bloomington Planning Department. Environmental Agreements of Developments Database.

[k] Linda Thompson, City of Bloomington Planning Department, "Conservancy Easements Database", 24 August 2012. Addresses (area): 2401 W. Tapp Road (59 acres); 3600 N. Prow Road (acres N/A); 3201 S. Wickens Street (acres N/A); 2310 W. 3rd Street (acres N/A); 1300 W. Countryside Lane (1.057 acres); 1201 S. Smith Road (acres N/A); 751 E. Tamarack Trail (1.78 acres); 2107 W. 3rd Street (17.27 acres); 3111 S. Walnut Street Pike (acres N/A); 2410 E. Moores Pike (acres N/A).

[l] Acreage Inventory data obtained from Dave Williams, City of Bloomington Parks & Recreation Department, 08 June 2012. Note: only based on "developed" acreage in Broadview Park, Bryan Park, Building & Trades Park, Upper and Lower Cascades Park, Crestmont Park, Ferguson Park, Griffy Lake Nature Preserve, Highland Village Park, Leonard Springs Nature Park, Maple Heights Park, Miller-Showers Park, Olcott Park, Park Ridge Park, Park Ridge East Park, Peoples Park, RCA Community Park, Reverend Butler Park, Schmalz Farm Park, Seminary Park, Sherwood Oaks Park, Southeast Park, and Third Street Park.

[m] Visited www.greenspots.in and spoke with Mike Hicks, Capital Projects Manager, City of Bloomington Utilities, 25 June 2012 and Steve Cotter, Natural Resources Manager, City of Bloomington Parks and Recreation, 2 July 2012. Note: Utilities Department Administrative Office Building, located on 600 E. Miller Drive, has pervious pavement, rain gardens, a bioswale with native plantings. Miller-Showers Park, located on 1500 N. College Avenue, has large detention ponds that retain storm water draining from over 170 acres of downtown Bloomington. Griffy Lake Nature Preserve, located at 3300 N. Headley Road, has 2 rain gardens filtering runoff from parking area before it enters the lake. Lower Cascades Park has a pervious pavement parking lot. Bryan Park has a native riparian buffer along its creek. The Goat Farm located along the Jackson Creek Trail near the Sherwood Oaks Park has a native riparian buffer along Jackson Creek and in the floodplain.

[n] 1. Sycamore Land Trust holds two conservation easements within Bloomington city limits. One is 16 acres on Lot 1 and Lot 2 of the Sakes Tarzian Subdivision. The county assessor's property cards list the addresses for these lots as 1113 E. Hillside Drive and 1020 S. Highland Avenue. The easement was recorded as instrument #2002007421 on 4/1/2002 and rerecorded as instrument #2012003734 on 3/9/2012. The other easement is about 0.2 acres, covering the south half of Lots 9 and 10 of the Allendale Addition. The property address is 717 S. Henderson Street. The easement was recorded as instrument #2002030757 on 12/19/2002. (John Lawrence, Assistant Director of Sycamore Land Trust, personal communication, 20 June 2012). 2. Bloomington Parks and Recreation holds two parcels at Griffy Lake that have official conservation easements: the original state-dedicated Griffy Woods Nature Preserve, which included 240 acres, and the 10-acre Schneider property, which was added to the state-dedicated preserve. (Steve Cotter, Natural Resources Manager, Bloomington Parks and Recreation).

[o] City of Bloomington Environmental Commission & C. Winkle. 2007. Greenspace trends in Bloomington, Indiana 1993-2007. City of Bloomington, Indiana. 11pp. Available online at https://bloomington.in.gov/media/media/application/pdf/2738.pdf. Last accessed 30 June 2011.

[p] Chuck Winkle, City of Bloomington GIS, 24 August 2012. Note: Includes hospitals and other facilities, such as nursing homes, that provide overnight care for patients that will eventually return home after short-term or medium-term stays. Facilities: Jill's House at 751 E. Tamarack Trail, Bloomington, Indiana 47408; Golden Living Center at 155 E. Burks Drive, Bloomington, IN 47401; IU Health Bloomington Hospital at 601 W. 2nd Street, Bloomington, IN 47403; Meadowood Retirement Community at 2455 N. Tamarack Trail, Bloomington, IN 47408; Monroe House at 2770 S. Adams Street, Bloomington, IN 47403; Bloomington Nursing and Rehabilitation Center at 120 E. Miller Drive, Bloomington, IN 47401.

[q] Chuck Winkle, City of Bloomington GIS, 24 August 2012. Note: Includes both Public and Private schools.

DEFINITIONS

BACKGROUND
Ecosystem Services: *benefits provided to humans by the elements, functions, and processes of living systems (natural or man-made); includes both goods (e.g., food, water, timber, fiber) and services (e.g., water and air purification, pollination) derived from nature.* *"Ecosystem services consist of flows of materials, energy, and information from natural capital stocks [ecosystems] which combine with manufactured and human capital services to produce human welfare."* (Costanza et al. 1997: 254)
Green Infrastructure: *the living elements and features serving as infrastructure in cities, including trees, parks, gardens, private yards, vegetated street medians and rights-of-way, vegetated detention ponds, and green roofs.*
Urban Ecosystem: *consists of the biophysical environment (natural and human-built) and human community and social structure, as well as the interactions between the natural and human elements in cities, towns and urbanized (or urbanizing) areas.*
STORMWATER MANAGEMENT
Bioswale: *area designed to direct stormwater runoff through a series of vegetated or gravel swales, or a low-lying area to which water naturally flows; vegetation can filter silt and pollutants from the water, as well as slow the flow of surface runoff.*
Combined Sewer Overflow (CSO): *an overflow of the stormwater sewer system, resulting in discharge of combined sewer water (stormwater, domestic sewage, and industrial waste water) into local water channels; occur due to overloaded stormwater systems.*
Green Roof: *rooftop engineered to support plant life (soil or substrate and vegetation), in order to absorb rainfall and decrease building energy usage for cooling.*
Impervious (or Impermeable) Surface: *surfaces composed of materials that do not allow water to penetrate into the ground, but instead cause rainwater to become runoff.*
Low Impact Development (LID): *a suite of development methods that aim to minimize the impact that development has on the on- and off-site stormwater quality and quantity (runoff) and enhance the environmental performance of a site; includes use of green infrastructure and site design principles that consider the existing, natural topography, geology and plant ecology of the site (EPA 2007).*
Natural Landscaping: *creates greenspace by mimicking what works naturally in our own geographic location; also provides ecosystem services like stormwater filtration, animal habitats and low-maintenance ground cover.*
Pervious Concrete: *concrete with a high porosity (ratio of air space to filled space) and permeability, allowing water to seep through the concrete rather than pooling on the surface.*
Pervious (or Permeable) Surface: *surfaces (ground, rooftop, etc.) composed of materials that allow water to permeate, or seep into, the underlying substrate (generally, the ground).*
Rain Garden: *low-lying area, landscaped with water-friendly vegetation (either wetland-specific plants or plants that can tolerate very wet soil); designed to slow surface runoff as well as filter pollutants.*
Urban Forest: *the sum total of all the trees in the urban area; includes park trees, street trees, trees in private yards, as well as remnant and planted woodlots.*

URBAN HEAT ISLAND EFFECT
Albedo: *the reflectivity of the Earth's surfaces, as measured by the amount of the sun's energy that a surface is capable of reflecting back (as opposed to absorbing); lighter colored surfaces have a higher albedo, and reflect a greater percentage of the sun's incoming rays, than darker surfaces.*
Boundary Layer: *the air or atmosphere above the tops of trees and buildings in a city (above canopy-level).* ***Canopy-Level:*** *the air in a city between ground-level and the tops of trees and buildings.* *See also Figure 2.*
Evapotranspiration: *the combined capacity of plants to evaporate (move water from the surfaces of the plant and surrounding soil to the air) and transpire (move water from within the plant, from roots, up through the leaves to the air); results in decreased local temperatures due to the heat used in changing liquid water to vapor form (similar to human evaporative cooling through sweating).*
Temperature Differential: *the difference, in degrees, between rural temperatures and urban temperatures of the same medium (rural air compared to urban air temperature, surface to surface).*
Urban Heat Island (UHI): *the resulting higher surface, sub-surface and/or air temperatures in cities, towns and urban (and urbanizing) areas, when compared to temperatures in the surrounding rural areas.*
Waste Heat: *extra energy (in the form of heat), produced by machines, that is not used; waste heat is produced during the combustion of fossil fuels by cars and emitted from buildings during heating and air conditioning.*
FOOD FROM URBAN AGRICULTURE
Community Garden: *a piece of land with plots rented by individuals or groups to grow food for their personal use.*
Community Supported Agriculture (CSA): *consists of a group of individuals who pledge support to a farm operation so that the farmland becomes, either legally or spiritually, the community's farm, with the growers and consumers providing mutual support and sharing the risks and benefits of food production. Typically, members or "share-holders" of the farm or garden pledge in advance to cover the anticipated costs of the farm operation and farmer's salary. In return, they receive shares in the farm's bounty throughout the growing season, as well as satisfaction gained from reconnecting to the land and participating directly in food production.*
Edible Landscaping: *the use of food-producing plants in the residential landscape; may include combining fruit and nut trees, berry bushes, vegetables, herbs, edible flowers, and ornamental plants into aesthetically pleasing designs.*
Food Desert: *an area where residents have limited access to supermarkets and supercenter stores, especially those that stock fresh fruit and vegetables.*
Food Safety: *exists when available food products will not harm the consumer when eaten in the manner intended for a particular food.*
Food Scarcity: *exists when people lack access to sufficient amounts of safe and nutritious food, which may be due to the unavailability of food, inadequate purchasing power, or inappropriate utilization at household level.*
Garden Tower: *a self-contained vertical garden and composting system invented locally by a Bloomington resident.*
Greenhouse: *a glass structure with a controlled environment that is used for the cultivation or protection of plants*
Grow Bag: *a hanging container filled with sterile growth medium and nutrients designed to enable a plant to be fully grown within itself.*
Living Wall: *a self-sufficient vertical form of garden that attaches to the exterior or interior of a building. Living walls differ from green façades (e.g. ivy walls) in that the plants root in a structural support which is fastened to the wall itself.*

The plants receive water and nutrients from within the vertical support instead of from the ground.
Peri-Urban Farm: *agriculture units located close to town on the urban fringe that operate intensive semi- or fully-commercial farms to grow vegetables, raise livestock, and produce milk and eggs.*
Raised Garden Bed: *usually framed by some type of barrier such as timber or stone, these containers are elevated above ground level in areas where poor quality soil exists so that better quality soil can be placed into the beds*
Sustainable Agriculture: *is an integrated system of plant and animal production practices having a site-specific application that will over the long-term (1) satisfy human food and fiber needs, (2) enhance environmental quality and the natural resource base upon which the agriculture economy depends, (3) make the most efficient use of nonrenewable resources and on-farm resources and integrate natural biological cycles and controls, (4) sustain the economic viability of farm operations and (5) enhance the quality of life for farmers and society as a whole.*
Urban Agriculture: *the growing of plants and the raising of animals within and around cities.*
Vertical Farming: *a proposed agricultural technique involving large-scale farming in urban high-rises or "farmscrapers" that uses recycled resources and greenhouse methods to produce fresh food year-round.*
HUMAN HEALTH AND WELL-BEING
Human Health and Well-being: *"a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."* (World Health Organization, as quoted in Tzoulas et al. 2007).
Physiological: *related to the human body's biological, physical, and chemical functioning.*
Restorative Experience: *an experience that allows a person to recover from a situation of intense stress, excitement, or other period of significant effort; an opportunity to recharge following mental or physical exertion.*
WILDLIFE HABITAT AND BIODIVERSITY
Backyard Wildlife Habitat: *small, naturalized landscapes (many times, in people's back or front yards) that intentionally provide habitat for urban wildlife and are designed to attract birds, butterflies and/or small mammals.* *You can get information on how to create your own Backyard Wildlife Habitat at the EC's Natural Landscaping website. Then, visit the National Wildlife Federation's Backyard Wildlife Habitat webpage to get your yard registered!*
Biodiversity: *the wealth of genetic and species diversity that comprises an ecological community; diversity implies variation both within and between species populations, as well as the total number of species in an ecological community.*
Ecological Community: *a group of organisms living in the same place and interacting with one another; individual organisms and groups of species interact with one another through competition for food, water and shelter, and through predation and the food web.*
Habitat Patches: *small areas of suitable wildlife habitat (vegetation) surrounded by a matrix of urban land uses, including buildings, roads, parking lots, and waterways.*
Invasive Species: *non-native (or exotic) plants, animals, or microbes that proliferate and spread in ecosystems, causing economic, human health, or environmental damage.*
Population: *a group of individuals of the same species living in a geographically distinct location.*
Wildlife Habitat: *areas where animals can find food, shelter and other needs for survival.*

THREATS TO GREEN INFRASTRUCTURE

Greenspace: *open land in a natural, restored, or landscaped state, including vegetation and forested areas as well as grassy fields or park land.*

The City of Bloomington Environmental Commission greenspace analyses and reports defines greenspace as land that meets three criteria:

1) *"The area must possess a permeable surface."*
2) *"The area must be greater than one contiguous acre."*
3) *"The area must be more than ten feet from any manmade development, such as roads, parking lots, and buildings."*

(Bloomington Environmental Commission (BEC) & Chuck Winkle 2007: 1)

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